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THESIS

A DECISION SUPPORT SYSTEM FOR SEA-BASED
SUSTAINMENT OPERATIONS

by

Norman L. Reitter

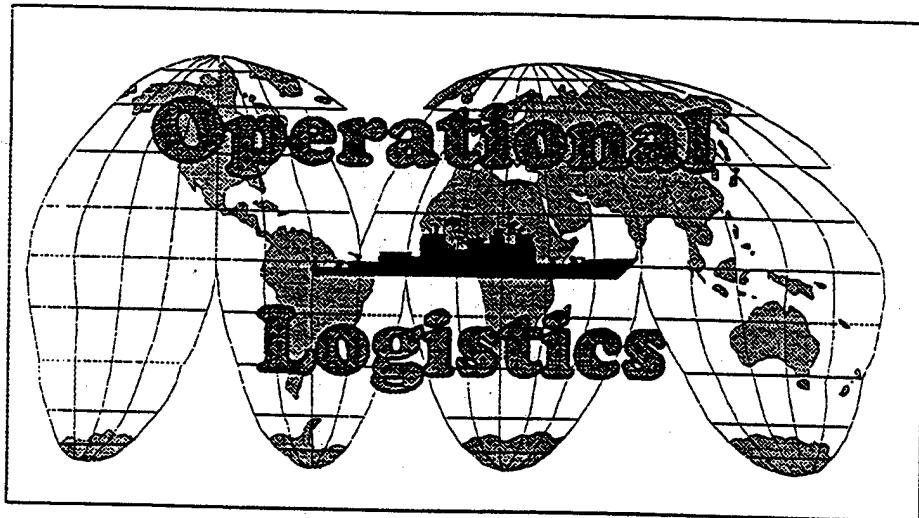
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Thesis Advisors:
Second Reader:

David A. Schrady
Gordon Bradley

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*Amateurs discuss strategy,
Professionals study logistics*



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**A DECISION SUPPORT SYSTEM FOR SEA-BASED SUSTAINMENT
OPERATIONS**

Norman Lyle Reitter
Captain, United States Marine Corps
B.S., United States Naval Academy, 1993

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September 1999

Author:

Norm L. Reitter

Norman L. Reitter

Approved by:

David A. Schrady

David A. Schrady, Thesis Advisor

Gordon B. Bradley

Gordon B. Bradley, Second Reader

Richard E. Rosenthal

Richard E. Rosenthal, Chairman
Department of Operations Research

ABSTRACT

The Marine Corps plans to fight battles in the 21st century using the littoral battlespace to maneuver forces from a sea-base to the operational objective. Combat forces ashore will be sustained directly from a sea-base to allow combat elements to maneuver freely without having to defend a rear area. In this type of environment, planners must be able to convert current data, intelligence, and status reports of units ashore into useful planning information. A sea-based sustainment posture makes transportation assets in the ship-to-objective delivery network critical for sustainment.

This thesis focuses on sustainment and distribution in a sea-based environment. The Sea-based Logistics Decision Support System (SBLDSS) is developed to assist sustainment planners in this environment to predict inventory levels of forces ashore and assist in managing transportation assets. First, typical forces are modeled to reflect both their composition and activities ashore. Resupply needs are determined based on the commander's concept of operations and logistics planning factors developed for each force. Transportation assets, used to sustain the forces, are modeled. Demand is then placed on these transporters by both logistical and operational missions. Finally, a utilization schedule is constructed to determine if a feasible distribution plan exists.

DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the planner.

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LIST OF SYMBOLS, ACRONYMS AND/OR ABBREVIATIONS

AAAV	Advanced Assault Amphibious Vehicle
ACE	Aviation Combat Element of a MAGTF
BA	Basic Allowance
BLT	Battalion Landing Team
CAAT	Combined Anti-Armor Team
CE	Command Element of a MAGTF
CSSE	Combat Service Support Element of a MAGTF
DOS	Days of Supply
GCE	Ground Combat Element of a MAGTF
HST	Helicopter Support Team
LAV	Light Armored Vehicle
LFSP	Landing Force Support Party
LPF	Logistics Planning Factor
MAGTF	Marine Air Ground Task Force
MCSSD	Mobile Combat Service Support Detachment
MEDEVAC	Medical Evacuation
MEU(SOC)	Marine Expeditionary Unit, Special Operations Capable
MTMCP	Multiple Tour Maximum Collection Problem
OMFTS	Operational Maneuver From The Sea
OTH	Over The Horizon
STOD	Ship-to-Objective Delivery
STOM	Ship-to-Objective Maneuver
SOA	Sustained Operations Ashore
SBL	Sea-based Logistics
T/E	Table of Equipment
T/O	Table of Organization
TOS	Time on Station
TOT	Time on Target

EXECUTIVE SUMMARY

As the Marine Corps continues to develop its 21st Century Warfighting Concepts, it needs a planning tool to assist operators and logisticians in planning littoral operations. Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM) and Sea-based Logistics (SBL) define how the Marine Corps will conduct littoral operations in the 21st Century. These concepts diverge from traditional ship-to-shore operations by maneuvering combat forces directly from a sea-base to operational objectives deep inland without first building up logistical bases ashore. By using the sea as a maneuver space, Marines will out maneuver the enemy through deception operations, rapidly collect and process data into information, and make decisions before the enemy has time to react. The forces operating ashore will have minimal sustainment in the form of commodity inventory levels. By reducing the heavy logistics burden associated with these inventories, they will maneuver more freely to secure objective areas without establishing a land line of communication to a beach support area. This flexibility comes at the cost of placing heavy demand on the ship-to-objective distribution network needed to provide reliable and responsive logistics support to these combat forces.

The sea-based ship-to-objective delivery (STOD) network will be supported primarily by the MV-22 Osprey and CH-53E Super Stallion vertical replenishment aircraft. Sea-basing logistics assets implies that logistic resupply missions will demand more aircraft than during traditional littoral operations, competing with tactical missions

already required to accomplish the commander's concept of operations ashore. To properly manage these scarce transportation resources at the sea-base, operational and logistics planners need to anticipate the resupply requirements of the combat forces operating ashore and plan for the additional demand placed on the aircraft by emergent resupply requests.

This thesis provides a stand-alone program, the Sea-based Logistics Decision Support System (SBLDSS), that assists planners in determining sustainment requirements of forces ashore and managing the aircraft at the sea-base. The SBLDSS provides planners an easy-to-use graphical user interface to model the force structure ashore, the transportation assets at the sea-base, and the tasks the forces and transporters need to accomplish. The planner is able to model each force's food, water, fuel, and ammunition consumption by either using the logistics planning factors developed for each force module or by developing their own and editing the program's default values. The forces can then be tasked through events, already built-in to the support system, that model typical actions of forces operating in a land combat environment. These events, the logistics planning factors of each force, and passage of time drive a commodity inventory model that allows planners to anticipate emergent resupply requirements. Transportation assets at the sea-base can be modeled and tasked with both operational and logistics resupply missions. Finally, the planners are able to use an aircraft-scheduling algorithm to tell them if the sustainment plan is feasible. The schedule provides them information for managing the aircraft assets more efficiently.

This thesis provides a planning tool that uses data from the forces ashore, applies operations research techniques to the problem, and produces useful information for planners operating in a sea-based environment. The Marine Corps 21st Century Warfighting Concepts will not be realized until a planning tool, with a capability like the SBLDSS, emerges to properly manage limited sea-based transportation assets required to sustain operational forces ashore.

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I. INTRODUCTION

Transformation from a landbased to a seabased support system will require nothing less than a revolution in logistics functions and applications. [Ref. 1]

CSS Branch, Requirements Division,
MCCDC

The Marine Corps plans to fight battles in the 21st century using the littoral battlespace to maneuver forces from a sea-base to the operational objective. Operational Maneuver From The Sea (OMFTS) and Ship-to-Objective Maneuver (STOM) are the cornerstones for how the Marine Corps expects to develop this type of warfare. Sea-based Logistics (SBL) focuses on how this type of warfare will be logistically supported.

OMFTS is not a new concept. During World War II, both the Army and the Marine Corps used operational maneuver from amphibious shipping to outflank the Axis powers in Northern Africa, Europe, and during the Island-hopping campaign in the Pacific. STOM diverges from the classic amphibious warfare by moving through the littoral area without an operational pause. By using emergent technology for information processing and rapid planning, Marine Forces will out-maneuver and overcome the enemy.

SBL is the concept that discusses how the Marine Corps will sustain the combat forces ashore. Sea-based combat service support (CSS) will be delivered directly to the friendly forces in the objective area. Reduced sustainment inventories ashore will provide maneuver forces greater speed and maneuverability. In this type of environment, planners

must be able to convert current data, intelligence, and status reports of units ashore into useful planning information. This will allow them to quickly and efficiently evaluate the commander's courses of action and determine the best concept of operations with a feasible sustainment plan.

Proactive logistics planning is crucial in the SBL environment. The very nature of the pull of forces' logistics requests, coupled with reduced inventory carrying capacity of these forces, make the transportation assets in the delivery network critical for sustainment. Inventory levels of logistics drivers ashore must be predicted, resupply requests must be anticipated, and transportation assets must be judiciously managed. This thesis focuses on sustainment and distribution in a sea-based environment.

A planning tool, the Sea-based Logistics Decision Support System (SBLDSS), is developed to assist planners in a sea-based environment to predict inventory levels of forces ashore and to assist in managing transportation assets. First, typical combat, combat support, and combat service support units, expected to participate in operations ashore, are modeled to reflect both their composition and activities ashore. Resupply needs are then determined based on the commander's concept of operations and logistics planning factors developed for each force. Transportation assets, used to sustain the forces, are modeled. Demand is then placed on these transporters by both logistical and operational missions. Finally, a utilization schedule is constructed to determine if a feasible distribution plan exists.

II. BACKGROUND

Always recognized as the critical element in any military campaign (tacticians worry about battles; strategists worry about logistics), although often neglected, logistics must now evolve to accommodate the new strategy of the Navy and Marine Corps operating within a joint environment. [Ref. 2]

1999 Naval Studies Board

I don't know what the hell logistics is...but I want some of it!

Fleet Admiral Ernest King, USN

The purpose of this chapter is to provide the reader with an overview of the organizational structure and operational concepts modeled in this thesis. Marine Corps Warfighting Concepts, that describe how Marines will execute future operations, are discussed to lay the foundation for how the SBLDSS could be used in their support. Results of some prior studies are also discussed to highlight analysis that has already been done on this subject. These studies are used in modeling sea-based logistics in the SBLDSS.

A. MARINE CORPS WARFIGHTING CONCEPTS

The Marine Corps Warfighting Concepts, developed by the Concepts Division of the Marine Corps Combat Development Command (MCCDC), describe the intended direction of how the Marine Corps will fight in the 21st Century. These Concepts provide a basic idea of expected future operational conditions and methods for fighting battles during this timeframe. Several Marine Corps Concepts are used to develop this thesis.

1. Operational Maneuver From The Sea (OMFTS)

OMFTS [Ref. 3] is the first of a series of warfighting concepts that describe how the Marine Corps expects to fight future ground operations. OMFTS adapts the tradition of maneuver warfare to all aspects of warfare in and around coastal waters. In future concepts, the Marine Corps will need to provide sustainable forcible entry from the sea. OMFTS says operations will be high tempo in and between a wide variety of environments. Rapid decision making during these high tempo operations will prevent the enemy from responding quickly enough to the Marines' actions. OMFTS lists wargaming and combat simulation as two elements that will enhance this intuitive-based decision-making cycle. To prevent large logistics support areas from hindering maneuver warfare from the sea, a significant reduction of logistics assets is needed ashore.

2. Ship-to-Objective Maneuver (STOM)

STOM [Ref. 4] further defines how future OMFTS operations will be conducted by directly applying the principles and tactics of maneuver warfare to the littoral battlespace. STOM operations will be conducted with dispersed forces maneuvering over extended distances. Depending on enemy threat conditions, the Advanced Amphibious Assault Vehicle (AAAV), and the M1A1 Abrams Main Battle Tank will be sent to shore from over-the-horizon (OTH). The Landing Craft Air Cushioned (LCAC) vehicle, carrying the M1A1 from OTH, and the AAAV make up the surface tips of the triad expected to provide surface and air lift into the STOM environment. The MV-22 Osprey, planned to be fully operational in 2014, will become the principal aerial delivery asset for operational and sustainment missions. Using the sea as a maneuver space, the Marine

Corps will take advantage of fast delivery vehicles and its ability to penetrate the enemy shoreline at points of its own choosing. The Marine Corps will gain operational advantage through surprise, by using speed and deceptive feints with decoy assets. Once ashore, forces will advance through the littoral area without pausing at the beach. Instead, power will be projected deeply inland directly to the maneuver objectives. The combat service support footprint, normally established ashore, will be reduced to only those forces absolutely necessary to sustain forces ashore. "Freed from the constraints of securing a large beachhead, the commander will be able to focus on the enemy and begin the landing force's maneuver from over-the-horizon". [Ref. 4] Once maneuver units pass through the beach area, ground lines of communication will collapse behind them, placing reliance for sustainability on a vertical ship-to-objective delivery system.

3. Sustained Operations Ashore (SOA)

MAGTF in Sustained Operations Ashore (SOA) [Ref. 5] is a concept to describe how the Marine Corps could be employed in sustained joint operations ashore. SOA envisions the MAGTF remaining as a general-purpose force, but one capable of executing a series of precise, focused, combat actions rather than primarily participating in continuous methodical ground operations. SOA states that a sea-based Marine Force will be responsible for the Marine's service level administrative and logistics functions. In this concept, maneuver forces ashore will have limited organic logistics capabilities. Mobile combat service support elements (MCSSE) may be task organized to directly support the maneuver element's mission. The maneuver elements will only rely on an MCSSE in emergency situations. Direct support from the sea-base will be used for

routine resupply. Again, SOA emphasizes the requirement to rapidly plan complex operations. Sea basing is noted as the thread that ties OMFTS, STOM, and SOA together.

4. Sea-based Logistics (SBL)

The Sea-based Logistics Concept [Ref 6] describes operational and tactical sustainment of forces operating on and from the sea. This Concept describes a means to support littoral power projection from OTH, allowing Naval Forces to operate independently from sovereignty restrictions and overseas basing requirements. SBL will provide a unique capability to both sustain the expected future, high tempo, battlefield and exploit the advantage inherently found in mobility and OTH standoff of naval vessels.

The primary thrust of the Sea-based Logistics concept is to reduce or eliminate the logistics footprint ashore historically used in amphibious operations. Sustaining the full spectrum of littoral operations and coupling ship-to-objective distribution with network-based automated logistics information will provide the enabling element necessary to successfully realize this warfighting concept. The ship-to-objective distribution is noted as the keystone to SBL. “Managing finite lift resources to satisfy the broad range of operational and logistics missions will require close coordination” [Ref 6: p. XI-11] between operational and logistics planners. Finally, integrated tactical and logistics planning, to include course of action development and associated concepts of employment, will ensure the distribution assets are appropriately assigned to support the commander’s concept of operations ashore.

5. Recent Studies

Recent studies have focused on limitations of OMFTS based on transportation support from the sea-base. In 1997, LT Mark Beddoes stipulated available CSS assets can not support a traditional ground force mix, but can support smaller, infiltration-type units [Ref. 7]. He stated that naval amphibious shipping would desire at least 100 nautical miles of stand-off distance from ship-to-shore due to the enemy threat of mines, anti-ship missiles, diesel submarines and small coastal craft. His analysis showed that this shipping would need to move within 43 nautical miles from the shore to support Marine OMFTS operations longer than 15 days. The risk associated with enemy threat is significantly increased when the naval ships must position themselves within the 25 and 40 nautical mile ship-to-shore distance required for advanced assault amphibious vehicle (AAAV) and air cushioned landing craft (LCAC) deployment, respectively. In 1998, Maj Robert Hagan demonstrated the inherent difficulty of sea-based sustainment over the distances associated with OMFTS, 25 miles from ship-to-shore and 50 miles from shore-to-objective [Ref. 8]. In his thesis, he highlighted the difficulties of using air delivered sustainment to provide the logistical movement requirements of a Special Operations Capable Marine Expeditionary Unit (MEU (SOC)) in a wide range of operational missions.

B. FUTURE OPERATIONS IN LITTORAL AREAS

Future operations in littoral areas will be complex. Logistics and Operational planners must ensure redundancy and flexibility are incorporated into each sustainment plan. The Marine Corps future warfighting concepts focus on several key elements for

operations in littoral areas. These include smaller, mobile combat service support elements (MCSSE) ashore and dependence on a sea-base for sustainment ashore.

MCSSEs are expected to operate in direct support of combat units operating ashore. MCSSEs will be small, attached to combat units, and will not have a ground link to a traditional beach support area. This implies the MCSSEs must be mobile and provide organic defense so they minimize their impact on the combat units' main mission. Mobility will limit the supply storage capacity of the MCSSE, further increasing the risk of the combat unit running short on supplies. Without a direct ground link to a beach support area, MCSSEs will be solely dependent upon air transporters to deliver critical supplies at critical points in time to a specific location. Timing is a key planning element which places increased dependence on transporter capabilities, including availability, reliability, and vulnerability. Logistics planners must be able to minimize the high level of risk associated with transporters delivering critical supplies within limited time-windows of opportunity by predicting when units will require resupply and how best to employ the transporter assets available to carry out both the resupply and operational missions. These transportation assets, already tasked with providing direct operational support to combat units, must now also sustain the logistical distribution network.

Logistics planners must have an ability to predict inventory levels of forces operating ashore. The sea-based environment implies logistics planners must plan logistics support using a "logistical push" or anticipatory, style of logistics planning, while relying on a "logistical pull" style distribution network [Ref. 9]. The logistics distribution system will be reliant on close communication and coordination with the combat units to

ensure the critical timing for resupply is achieved. Also, logistics coordinators must be able to predict inventory levels of forces operating ashore to prevent reactive, myopic, operational tasking. By anticipating force logistics requirements, logistics coordinators will be able to prepare supplies and transporter vehicles on the sea-base to minimize the overall risk to force sustainment.

Once logistics coordinators have the ability to anticipate expected resupply missions, they will be able to better manage their transportation assets. The 1999 Naval Studies Board, [Ref. 2: Ch. 4, p. 8], describes how a transporter's carrying capacity is degraded with increased support radius. These findings imply that allocation of the small number of transporter assets will be critical for planning future sea-based operations that involve both logistics and operational missions.

III. DECISION SUPPORT SYSTEM OVERVIEW

Recommendation: The Marine Corps should start developing the logistics information systems, displays, and automated decision aids it will need to manage fast-paced, complex support operations in tomorrow's warfighting environment. [Ref. 2]

1999 Naval Studies Board

This chapter discusses requirements for logistics decision support systems and describes how the Sea-based Logistics Decision Support System (SBLDSS) can be used to fulfill this requirement. An overview of the SBLDSS also provides background for discussion of model development.

A. LOGISTICS DECISION SUPPORT SYSTEMS

Logistics decision support systems must provide the supported commander with useable information about combat and combat support forces sustainability. Using logistics planning factors to convert data to measurable information is the key to providing proactive sustainment plans and capturing the true logistics posture of forces. This idea is captured in the following quote:

Data becomes information with which to create a picture of the logistics of the forces on the battlefield, to predict the sustainability of these forces, and to evaluate alternative courses of action as they are affected by logistics when it has been processed by software built around models that transform input data (tons of ordnance or barrels of fuel for example) into measures of sustainability (days of supply for example).

Schrady [Ref. 10]

Finally, the logistics decision support system must allow the planner to select forces, determine their support requirements, and determine a feasible transportation plan.

B. SEA-BASED LOGISTICS DECISION SUPPORT SYSTEM

The Sea-based Logistics Decision Support System (SBLDSS) is a planning tool for operational and logistics planners operating in a sea-based environment. The amount of data and calculations associated with amphibious logistics planning is extensive. This often results in reactive, myopic, planning. The SBLDSS will allow logistics coordinators to incorporate operational plans into a decision support system that gives the commander predicted inventory status of Marines operating ashore and the number of transporters required to support resupply and movement operations 12, 24, 36, 48, and 72 hours in advance. This will allow for more proactive transportation and resupply planning. The SBLDSS program's primary function is to assist sustainment planners in determining feasible sustainment plans for the commander's concept of operations ashore. It provides the planner an ability to plan, track, and predict the usage and sea-based replenishment of food, water, fuel, and ammunition of ground forces operating ashore. It also provides an aircraft-scheduling tool to assist in determining if a feasible distribution plan exists. This helps aircraft planners better manage transportation assets.

1. Description of User

The SBLDSS requires an intelligent user. This user should be able to interpret operational plans, supply inventory reports, and transporter availability reports. The user is expected to enter Events into the SBLDSS to coincide with the Marine Air Ground Task Force (MAGTF) commander's concept of operations. These Events drive consumption rates and tasks transporters with missions. Since SBLDSS is designed as a planning tool, the user is expected to be involved in Marine Air Ground Task Force (MAGTF) Logistics

and Operational planning. As such, the user must be fully integrated into the operational and logistics planning cell. Situation and intelligence reports must be made available to the user and he must be familiar with the scheme of maneuver for elements operating ashore. Ground Combat Element logistics planners ashore, the plans section in the Aviation Combat Element, or a Sea-based Command Element planning section can use the SBLDSS for future logistics and transportation planning. To use the SBLDSS effectively, the user should be knowledgeable in logistics and aviation transportation assets' capabilities and limitations. Finally, the user is expected to be an operational and logistics planner either operating in a real-life operation or participating in a wargame. Throughout this thesis, the user will be identified as a planner.

2. Java Programming Language

Developed in Java [Ref. 11], the SBLDSS benefits from low-cost, modeling flexibility, and platform independence features associated with this programming language. The Java Virtual Machine, the only software required to run the program, is available for download from Sun Microsystems' World Wide Web site, www.sun.com, at no cost. The inherent modeling flexibility of the object-oriented programming language allows the user to easily add forces, change transportation characteristics, or improve the current modeling algorithms without changing the entire program. Since Java is platform independent, the operators and players in wargames have the flexibility to run the program on a variety of hardware located on a ship or in the office. Finally, the Java programming language provides an ideal programming environment to comply with the common

operating environment requirement mandated by the Defense Information Systems Agency for all Department of Defense programs.

3. Program Overview

SBLDSS is a man-in-the-loop decision support system. The program is designed to perform the multitudes of calculations involved in logistics and transportation planning and provide the planner useful planning information as output reports. The SBLDSS is a prototype planning tool for operational forces forward deployed. It can also be used as a pre-deployment wargaming tool. The planner begins using the program when the commander receives a mission order. Operational and logistic planning is concurrent to ensure operational plans are logically feasible. First, the program allows the planner to create forces operating ashore and aircraft supporting the distribution network. Next, the planner models what the forces are doing and the demand placed on the transportation assets by creating events and placing them on an event list. Resupply requirements are then determined through use of a commodity inventory prediction model. Next, the planner is able to generate sortie requirements before the force ashore places a request. Once this is done, an aircraft-scheduling algorithm identifies if the available aircraft are able to support the sustainment requirements of the forces ashore. If the distribution plan is feasible, the planner can move forward with evaluating another course of action. If not, the planner must either manage the aircraft to increase the number of available transportation assets or re-evaluate the resupply plan. Figure 1 shows the SBLDSS program flow diagram.

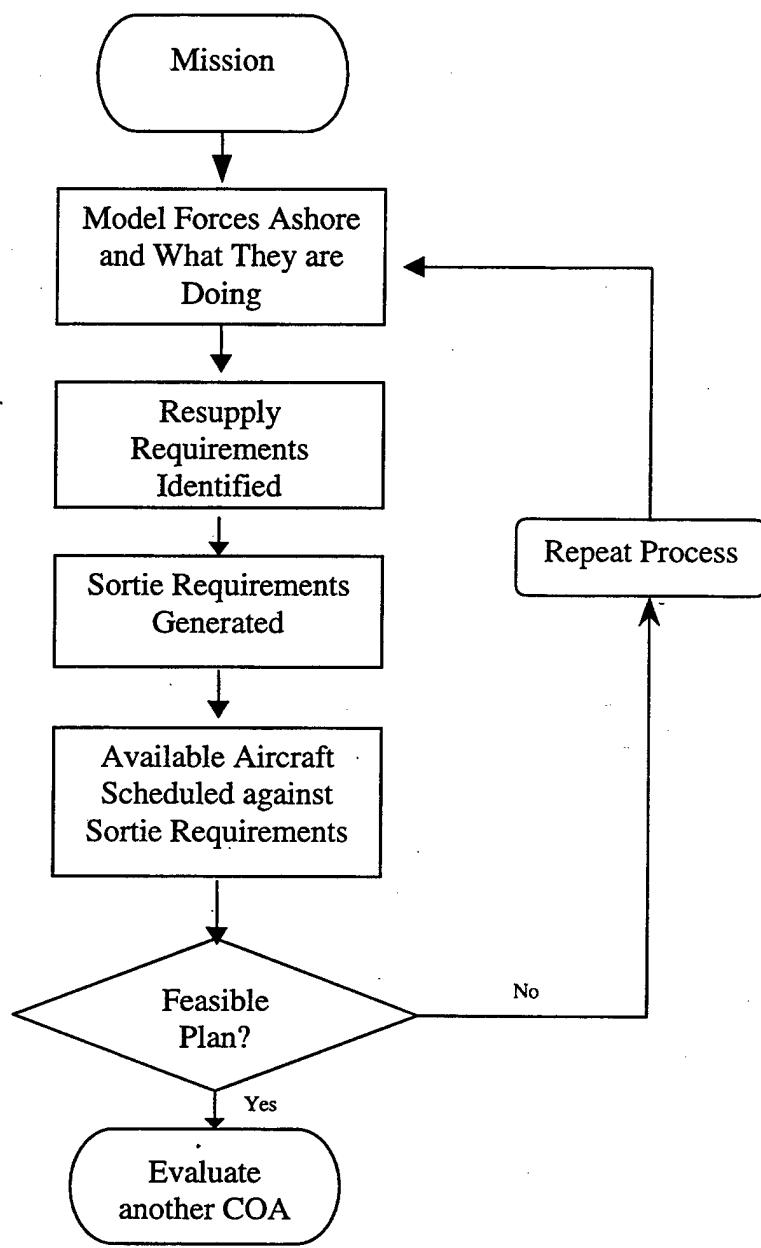


Figure 1: SBLDSS Program Flowchart

4. Setup

The Setup Menu allows the planner to specify characteristics of the forces operating ashore, and types and characteristics of aircraft. This section is completed before operations commence. Forces, Events, and Aircraft may be added to their respective lists. The planner must also define the operating environment during setup. Environment factors include enemy threat, operational tempo, and temperature. Enemy threat and operational tempo drive ammunition consumption. Temperature drives food and water consumption. Figure 2 shows the environmental setup options window in the SBLDSS.

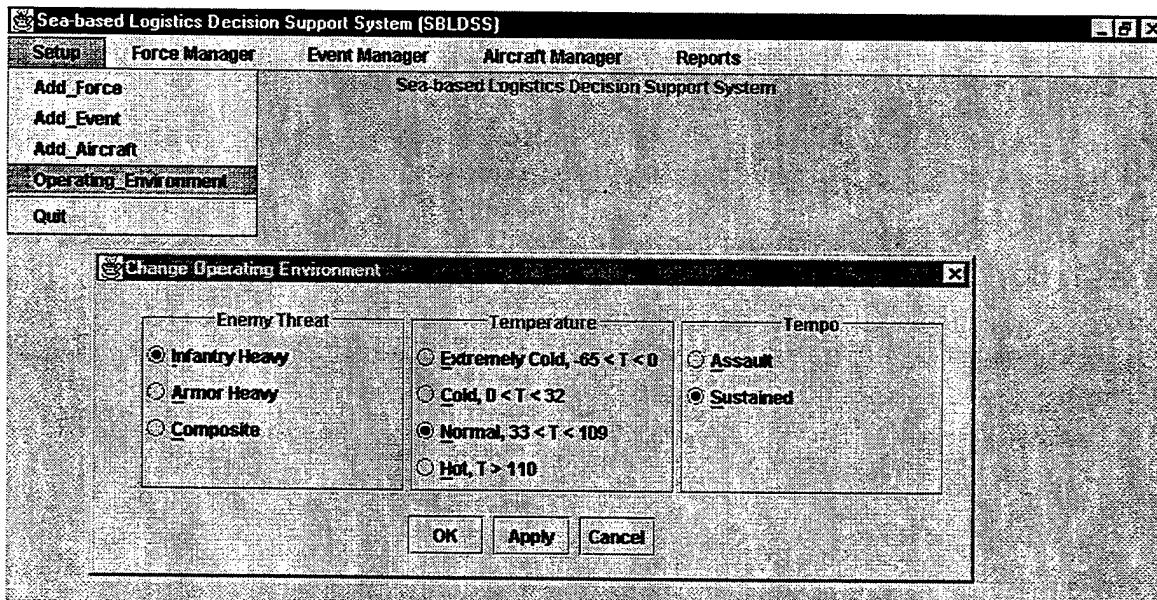


Figure 2: Operating Environment Window

5. Force Manager

The Force Manager Menu allows the planner to model forces ashore by providing typical combat, combat support, and combat service support units for selection. Figure 3 shows the Create New Force window.

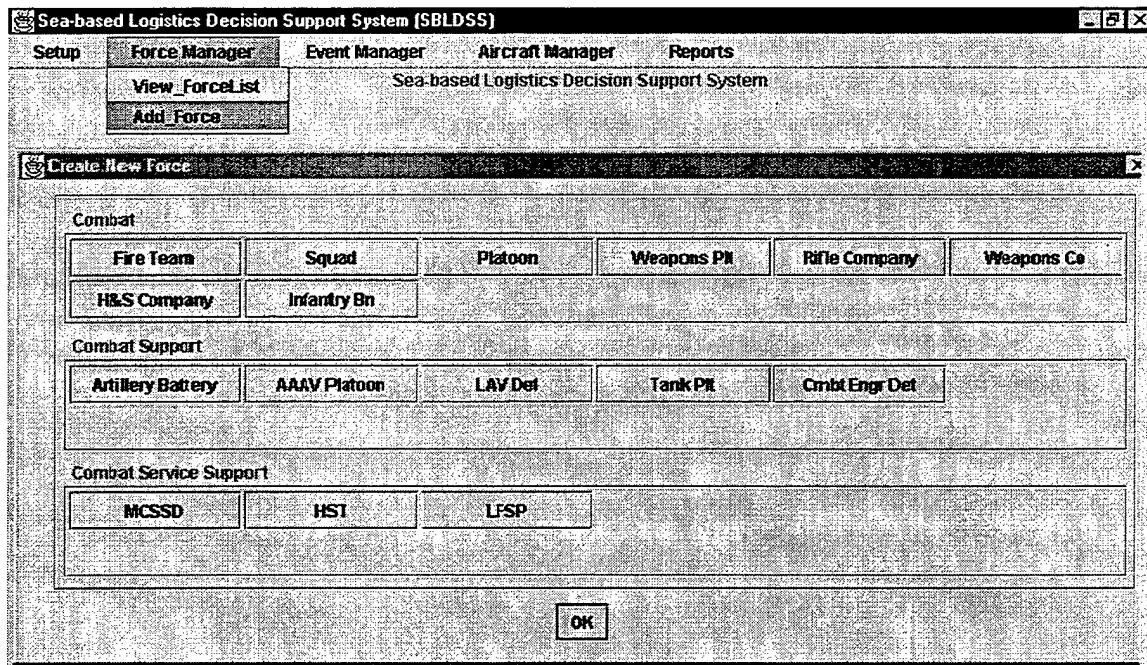


Figure 3: Create New Force Window

Logistics planning factors are developed from typical tables of organization (T/O) and tables of equipment (T/E), and are included for use in requirements and inventory prediction. Once the planner selects a force, he is then able to edit that force, and view all forces on the force list. The Create New Rifle Company Window, displayed in Figure 4, shows an example force edit window.

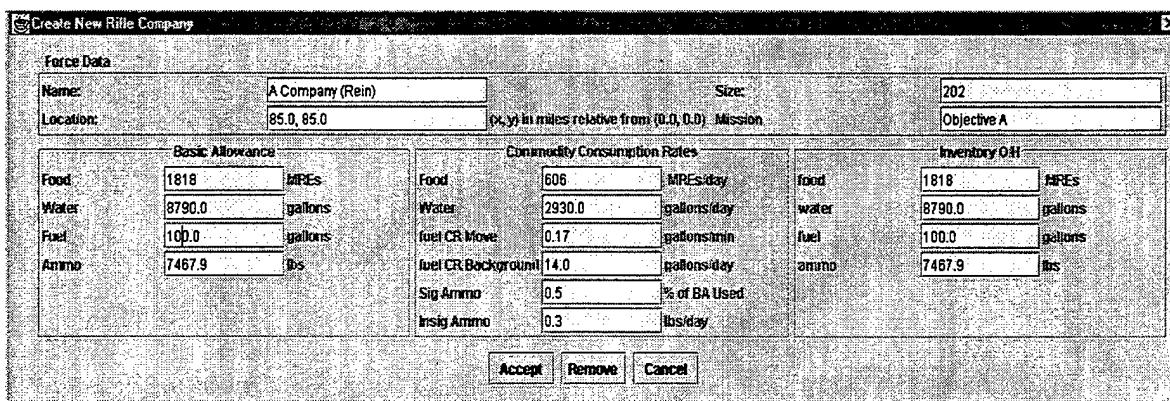


Figure 4: Create New Rifle Company Window

This edit window allows the planner to change a force's characteristics. The initial basic allowance, consumption rates, and force inventory planning factors were developed using Marine Corps planning factors from the MAGTF Data Library [Ref. 12] and Marine Corps Class V(W) Planning Factors for Fleet Marine Force Combat Operations. [Ref. 13] The basic allowance and commodity consumption rates are used for estimating commodity inventory levels. The initial commodity inventory levels are assumed to be the same as the force's basic allowance. The coordinate location, relative to the sea-base, is used to determine distance calculations in the scheduling algorithm. A description of the commodity consumption models and the scheduling algorithm is discussed in more detail in Chapter IV. Once a Force is created, it is added to the SBLDSS Force List. The Force List displays each Force created by the planner, its location, and commodity inventory levels. Figure 5 shows an example Force List.

Selected Force: B Company, Rifle Company							
Name	Type	Location	Mission	Food O/H(MRES)	Water O/H(gal)	Fuel O/H(gal)	Ammo O/H(lbs)
C Comp	Rifle Company	(30.0, 110.0)	Objective C	1638	8190.0	25.0	7073.4
A Comp	Rifle Company	(10.0, 100.0)	Objective A	1638	8190.0	25.0	7073.4
B Comp	Rifle Company	(20.0, 150.0)	Objective B	1638	8190.0	25.0	7073.4

Figure 5: Example Force List Window

6. Event Manager

The Event Manager is used by the planner to model force actions ashore based on the commander's scheme of maneuver and expected enemy actions. It also is used to task aircraft with missions in support of the forces ashore. Events are never automatically

entered into the model by the SBLDSS program. The intelligent planner must determine a specific time for each Event to occur and which forces are effected by the specific Event. When the planner creates an Event, it is added to an Event List with the associated date time group (DTG). This shows the user when the Event is to occur. SBLDSS uses two basic types of events: Force Events and Transporter Events.

a. Force Events

Force Events model operations of each force operating ashore and drive consumption of logistics commodities associated with these operations. Force Events drive the inventory consumption models, allowing the SBLDSS program to anticipate inventory levels of individual forces ashore. Force Events are scheduled by the planner based on the current Concept of Operations and enemy threat. The planner must be aware of the overall intelligence picture as the enemy has a direct effect on how forces ashore consume supplies, particularly fuel and ammunition. The planner must also be involved in operational planning to ensure maneuver plans are sustainable with the available transportation assets. Table 1 lists the Force Events used by the SBLDSS.

Event	Description
Move Force	Models a force movement from location a to location b
Movement to Contact	Models a force conducting a movement to contact mission against a known enemy threat and unknown enemy location.
Conduct Raid	Models a force conducting a limited engagement on a known enemy location.
Attack	Models a force conducting a full engagement on a known enemy location.
Withdrawal	Models a force withdrawing in the face of a constant enemy force
Defend	Models an expected attack against a specific force.
Idle	Models stand down periods for forces while still ashore.

Table 1. Force Events

Figure 6 shows the Create New Move Event Window. This is an example of the Force Event edit feature. This window appears after the planner selects the Force Event he wants to add to the Event List. It is found under the Add Force menu option under the Force Manager Menu. Force Event descriptions are discussed in greater detail during the discussion of consumption model development in the Chapter IV.

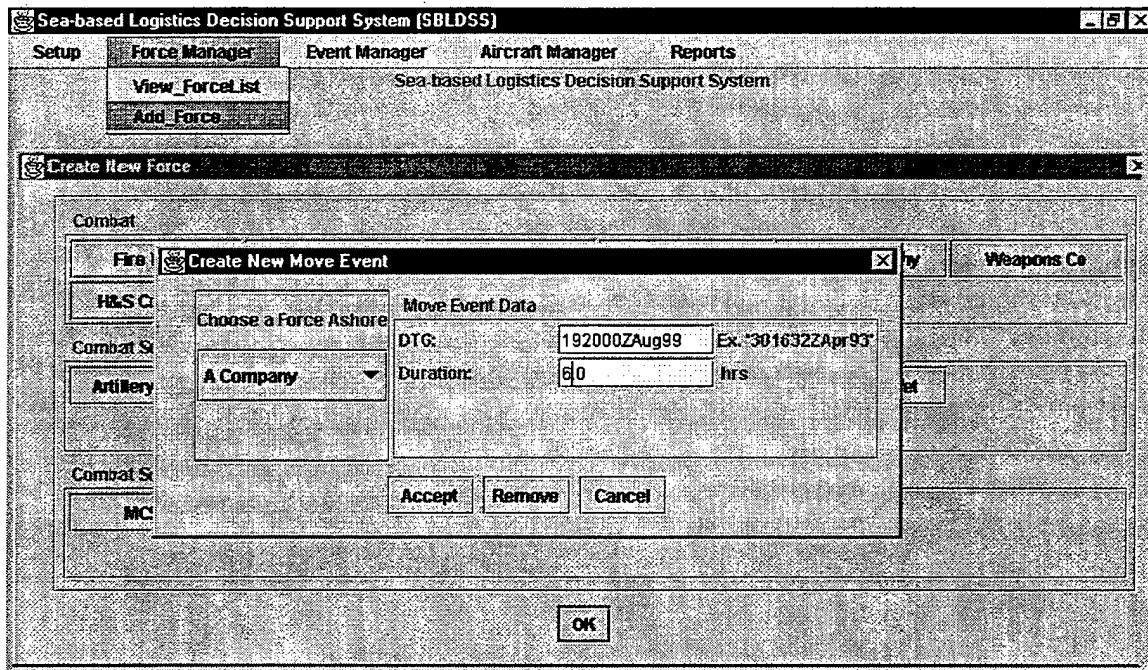


Figure 6: Create New Force Event

b. Transporter Events

Transporter Events allow the planner to add specific operational and logistics missions to the Event List that place demand on transportation assets. By modeling both operational and logistics missions, the planner is able to see the full impact of the commander's Concept of Operations on the distribution plan. Similar to the Force Events, Transporter Events are input into the SBLDSS by the planner based on the current Concept of Operations and Air Requests from the supported force. Table 2 describes the Transporter Events used by SBLDSS.

Event	Description
Emergent Resupply	Models a resupply mission to a particular force operating ashore requested by that force
Planned Resupply	Models an anticipated resupply mission to a particular force based on the planner's judgement and SBLDSS inventory reports
Force Move	Models a force movement from location a to location b by air extraction/insertion
MEDEVAC	Models a medical evacuation of a number of casualties from a specified force

Table 2. Transporter Events

The planner uses Resupply Events to anticipate the demand logistics resupply missions place on the sea-based transportation assets. Only single commodity Resupply Events are allowed in the SBLDSS. Resupply Events may be placed on the Event List for two reasons. Either the planner anticipates a resupply need based on a force's projected inventory level from the force's inventory report, or the planner receives a logistics Air Request from a force operating ashore. These two Events are called Planned Resupply Events and Emergent Resupply Events, respectively.

Force Move and MEDEVAC Events are used to model the operational demand placed on the sea-based transporters. The Force Move Event models aerial movement of a force from one location to another. The MEDEVAC Event is used when the planner either expects casualty evacuation or receives a request for evacuation from a specific

force. Figure 7 shows the Create New Resupply Event Window, selected from the Add Event option, which is found under either the Setup or the Event Manager menus.

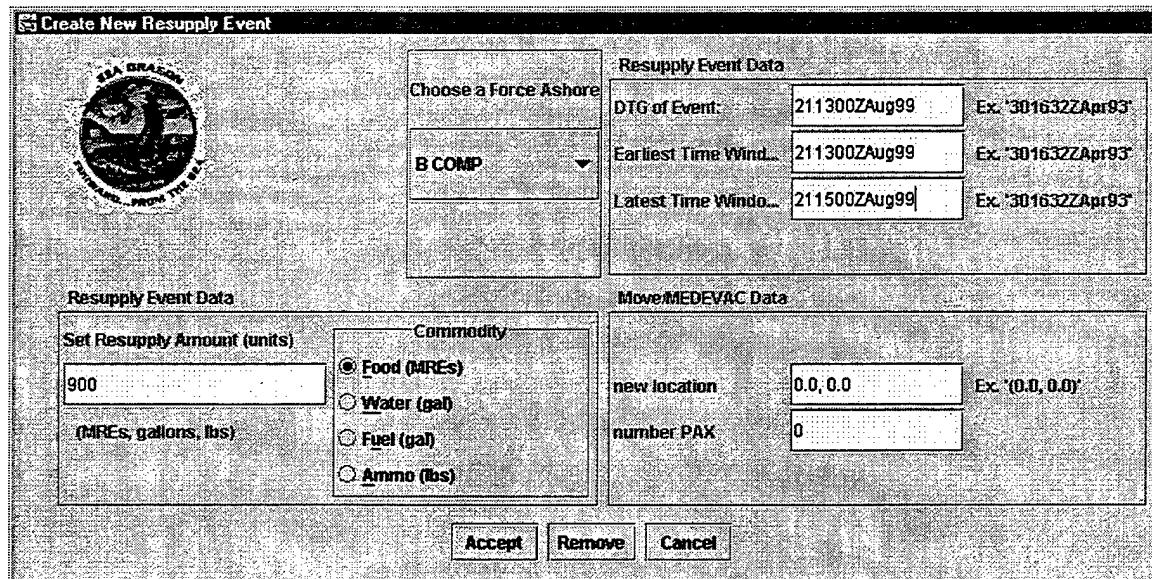


Figure 7: Create New Transporter Event Window

Once the planner creates Events, they are able to view the Events on the program's Event List. The Event List is used to ensure all force tasks in the commander's Concept of Operations are included in the program. The Event List displays the mission number, date-time group of when the Event is to occur, the type of Event, the time window in which aircraft must accomplish Transporter Events, and a message explaining the Force and description of the Event. The word "null" appears in the mission number column until the Aircraft Scheduler is solved. After the scheduler displays its output, the Event List will automatically update the new mission numbers for the Transporter Events. "N/A" appears in the Force Event columns to show that neither a mission number nor a time window is required for Force Events. Figure 8 shows how the Event List appears in the SBLDSS.

Event List

Add Event Remove Event Edit Event

Selected Event: A Co (Rein), resupply

Mission #	DTG	Event Type	Time Window	Message
N/A	170500ZAug99	Defend	N/A	N/A A Co (Rein)
null	170700ZAug99	resupply	170700ZAug99	170900ZAug99 Resupply A Co (Rein) 300.0 MREs
null	171000ZAug99	resupply	171000ZAug99	171100ZAug99 Resupply A Co (Rein) 3500.0 lbs of ammo
null	171200ZAug99	resupply	171200ZAug99	171700ZAug99 Resupply A Co (Rein) 2930.0 gallons of water
null	171700ZAug99	resupply	171700ZAug99	172000ZAug99 Resupply A Co (Rein) 300.0 MREs
null	171800ZAug99	resupply	171800ZAug99	172000ZAug99 Resupply A Co (Rein) 3500.0 lbs of ammo
N/A	172000ZAug99	MvmtToContact	N/A	N/A A Co (Rein)
N/A	180600ZAug99	Defend	N/A	N/A A Co (Rein)
null	180700ZAug99	resupply	180700ZAug99	181100ZAug99 Resupply A Co (Rein) 70.0 gallons of fuel
null	180700ZAug99	resupply	180700ZAug99	181000ZAug99 Resupply A Co (Rein) 300.0 MREs
null	181100ZAug99	resupply	181100ZAug99	181300ZAug99 Resupply A Co (Rein) 3200.0 lbs of ammo
null	181200ZAug99	resupply	181200ZAug99	182000ZAug99 Resupply A Co (Rein) 2390.0 gallons of water
null	181700ZAug99	resupply	181700ZAug99	182200ZAug99 Resupply A Co (Rein) 300.0 MREs
null	191200ZAug99	resupply	191200ZAug99	191700ZAug99 Resupply A Co (Rein) 3000.0 gallons of water
null	191600ZAug99	resupply	191600ZAug99	191900ZAug99 Resupply A Co (Rein) 600.0 MREs

Figure 8: Event List

7. Aircraft Manager

The Aircraft Manager menu provides the planner a transportation-planning tool to determine if available aircraft can feasibly support the planned concept of operations ashore. Expected future missions will impact aircraft availability. The planner is able to adjust transportation scheduling constraints, such as crew assignment and scheduled aircraft maintenance, to try to ensure the forces ashore can be sustained. The SBLDSS program is not designed as a scheduling tool; it is a planning tool to provide insight into upcoming mission requirements and expected number of transporters required to accomplish all the upcoming missions. From the Aircraft Manager menu, the planner is

able to create new aircraft and edit their characteristics either during setup or as the aircraft status changes. The planner can then view all the aircraft on the Transporter List along with their current availability, maintenance, and operational hour status. The planner is able to model missions not included in the SBLDSS as the Transporter Events, for example a deception flight, by setting the aircraft as unavailable for the current planning time horizon. This allows the user to decrease the number of available aircraft and realistically reflect the number of transportation assets available for the sustainment plan. The two types of aircraft, the MV-22 Osprey and the CH-53E Super Stallion, are discussed in more detail in Chapter IV. The setup windows for each of these aircraft are also displayed in their respective sections. Figure 9 shows an example Aircraft List found in the SBLDSS.

The Aircraft Scheduler provides the planner with information on whether the current distribution plan is feasible with the number of available aircraft. It is a planning tool and should not be used for operational aircraft scheduling. If a distribution plan is infeasible, the planner is able to adjust the number of available aircraft, adjust the maintenance schedule, or relax the crew operating limit. He can then recompute the schedule. This process can be repeated until either the planner finds a feasible distribution plan or realizes the distribution plan for the current course of action is infeasible.

The Aircraft Scheduler output includes four sections. The first section includes a recommended assignment of available aircraft to Transporter Events. Each feasible mission is shown including the sortie departure time, delivery time, and return time for the

Tail#	Type	Op Hrs	Maint	Check	Crew Limit	Available
1	MV22	1895.0	1925.0	8.0		no
2	MV22	1234.0	1275.0	8.0		no
3	MV22	1490.0	1525.0	8.0		yes
5	MV22	5896.0	5925.0	8.0		yes
6	MV22	1454.0	1500.0	8.0		yes
7	MV22	1123.0	1150.0	8.0		yes
8	MV22	3450.0	3500.0	8.0		yes
9	MV22	5642.0	5675.0	8.0		yes
10	MV22	4553.0	4600.0	8.0		yes
11	MV22	3113.0	3150.0	8.0		yes
12	MV22	1342.0	1375.0	8.0		yes
21	CH53E	34526.0	34575.0	8.0		yes
22	CH53E	303446.0	303475.0	8.0		yes
23	CH53E	304321.0	304350.0	8.0		yes
24	CH53E	65567.0	65600.0	8.0		no

Figure 9: Example Aircraft List Window

aircraft assigned to the mission. The amount of lift still required to complete the mission is also displayed. The second section shows the planner the restrictions that are causing the scheduler not to schedule missions to specific aircraft. This allows the planner to see how they can adjust their maintenance schedule, available aircraft, or change their sustainment plan to make it feasible with the available number of aircraft. The third section shows the planner the missions that were not scheduled during the selected planning horizon and includes the remaining requirement to complete the mission. The last section shows the planner the numbers of hours and sorties each aircraft accumulated based on the scheduler output. This allows the planner to see the potential impact of the

schedule on the available aircraft. Figure 10 shows an example output from the Aircraft Scheduler. The algorithm used in SBLDSS for aircraft scheduling is discussed in more detail in Chapter IV.

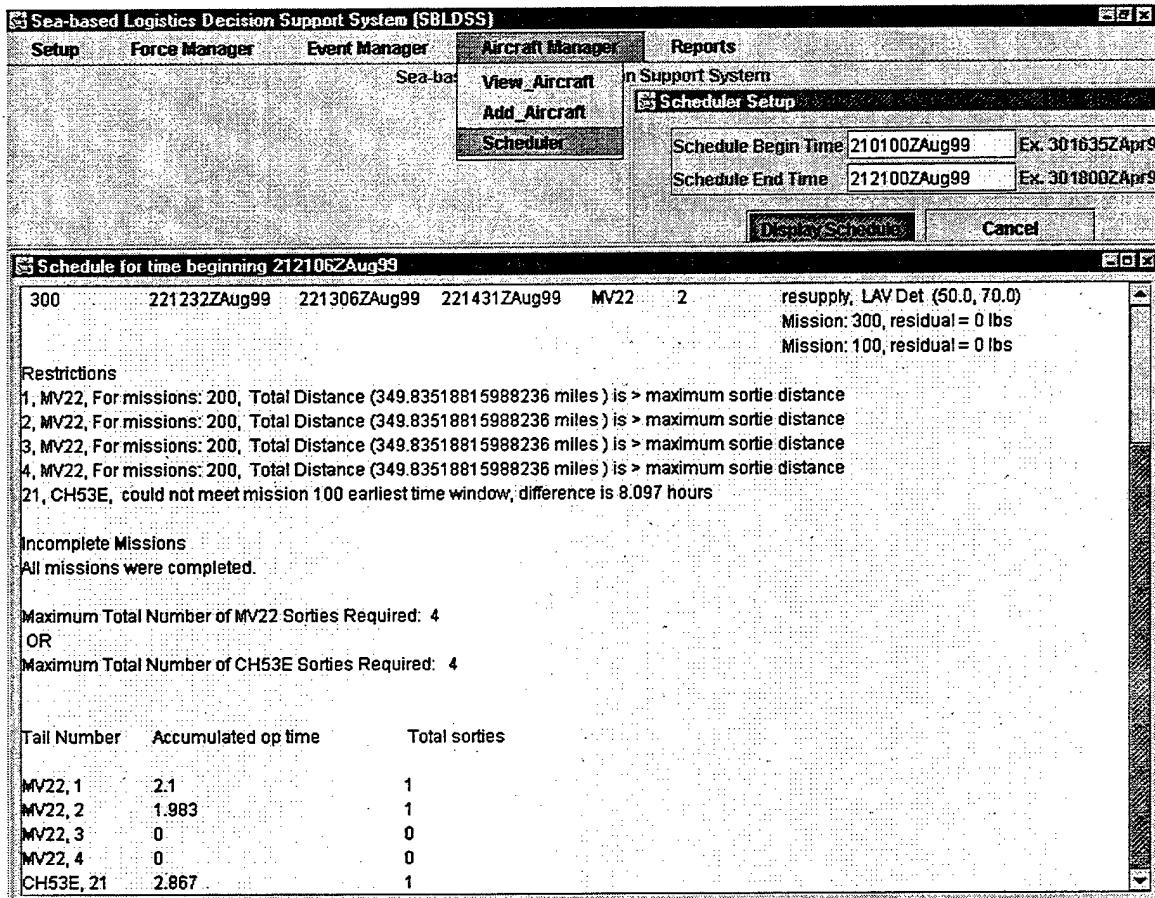


Figure 10: Example Schedule Output Window

8. Commodity Inventory Reports

After the planner completes the Event List, the planner can generate a Commodity Inventory Report for each Force based on usage, and the Events placed on the Event List. The commodity inventory report displays the expected food, water, fuel, and ammunition supply level 12, 24, 36, 48, and 72 hours from the current planning time. It also shows the planner the basic allowance and carrying capacity of the Force. The current

commodity level is based on the starting commodity level, the amount of the commodity delivered to the Force, and the amount of commodity used by the Force. By viewing the Forces' commodity inventory level at future time increments, the planner is able to anticipate when the Force will require resupply of a specific commodity before the Force submits a request. This allows the planner to place Planned Events on the Event List and solve the aircraft scheduler to ensure any emergent requests will not surprise the planner and cause an infeasible distribution plan. Instead, the planner is able to see if the number of available aircraft is adequate to support the commander's concept of operations ashore.

Figure 11 shows an example Commodity Inventory for a typical infantry rifle company.

It is found under the Reports Menu.

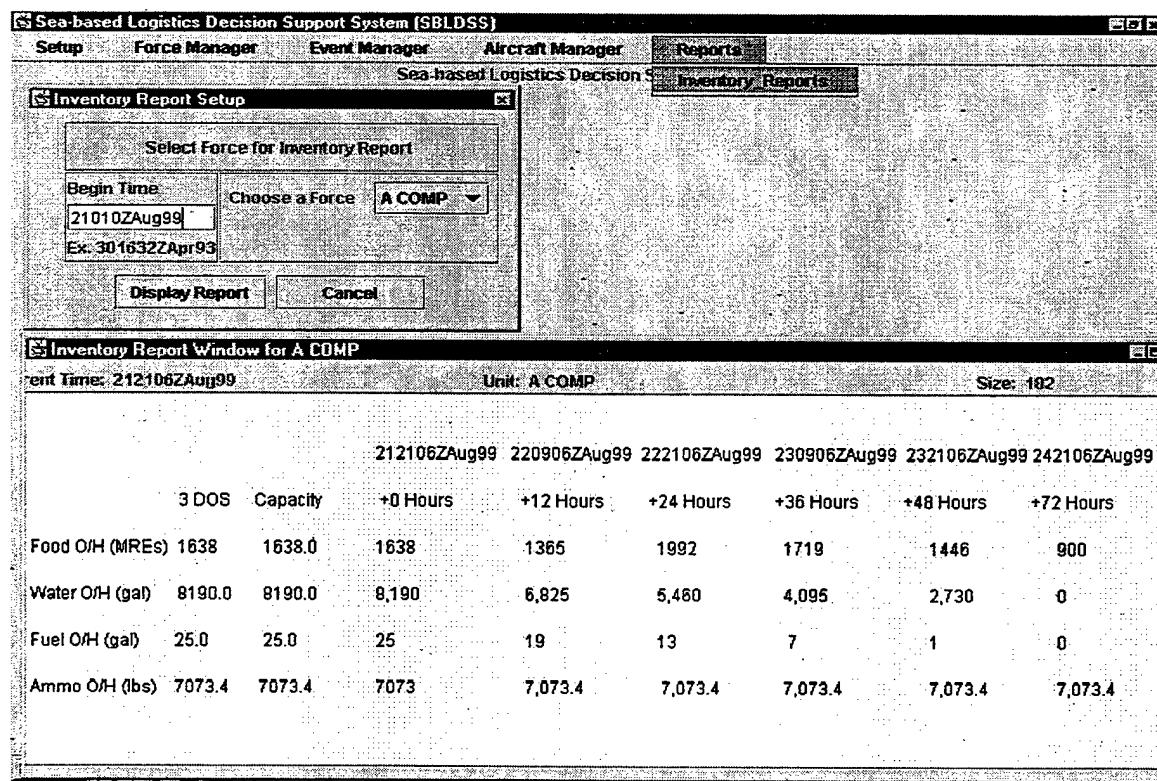


Figure 11: Commodity Inventory Report Window

IV. MODEL DEVELOPMENT

A. METHODOLOGY OVERVIEW

Modeling sea-based logistical and operational planning requires two distinct, but necessary, models: a sustainment model and a distribution model. The SBLDSS models sustainment through commodity consumption models and replenishment of forces ashore. Distribution is modeled using aircraft scheduling that is based on available aircraft and Transporter Events. This section provides an overview of how each model is developed. The following sections will offer greater detail. Both models depend upon planning factors that are created for three object entities; Force Modules, Events, and Transporters.

For this decision support system to be credible, each entity must realistically model current or future force structures, operations, and aircraft. The entities used in this model are a mixture of current forces and transportation assets expected to be operational after the year 2010. Various sized Force Modules give the planner flexibility to model various tactical scenarios in dispersed locations. Transporter entities vary in type, capabilities, and cargo capacities. This heterogeneous mix of transportation assets allows exploration into optimal mixes for specified missions. Once the modeling entities are defined, logistics planning factors are developed to reflect accurate supply consumption for the Force Modules and accurate transporter characteristics. Force Module consumption is dependent on the type of environment the force is operating in and the enemy threat. Transportation distribution capabilities depend on time, speed, and distance

relationships. The distance from the transporter's base to the forces ashore, both scheduled and corrective maintenance, and maximum crew operating times determine the availability of a transporter for a specific mission. Before discussing the force commodity inventory and the aircraft scheduling models, the three modelling entities are described in the next section.

B. MODEL ENTITIES

1. Marine Forces

Marine forces are modeled as Force Modules to reflect possible units operating ashore. Each Force Module is characterized by its number of personnel, number of weapons and weapon types, number of vehicles and equipment, and supply carrying capacities. These individual force characteristics drive commodity consumption and invoke constraints on each Force Module. Force Modules were developed to reflect all possible types of ground units from an infantry fire team up to a battalion landing team (BLT)-sized force. Units are segregated into three types: combat, combat support, and combat service support units. Larger units incorporate the smaller units into their tables of organization (T/O) and tables of equipment (T/E). Although these types of forces were modeled as the default forces for the SBLDSS, the planner is able to edit any characteristic, either during setup or while the program is in use, to reflect more accurate planning factors. If infantry, combat support, and combat service support units operate together as a task force, their characteristics must be combined to reflect accurate Force Module planning factors. In this case, the sum of each planning factor for the different types of units can be used as the planning factors for the new Force Module. The planner

may also modify a Force Module to reflect planning factors for modeling other units not offered as default units in the SBLDSS. For example, an Infantry Rifle Company could become an Infantry Regiment by renaming the company and replacing planning factors to reflect those expected of a regimental sized force. This gives planners the flexibility to realistically model forces under the current task organization ashore. It also allows analysts and wargamers to evaluate how different force structures effect the sea-based distribution problem. The SBLDSS default Force Modules are listed in Table 3.

Infantry Units	Combat Support Units	Combat Service Support Units
Fire Team	Artillery Battery	Helicopter Support Team (HST)
Squad	Tank Platoon	Landing Force Support Party (LFSP)
Platoon	LAV Detachment	
Weapons Platoon	AAAV Detachment	Mobile Combat Service Support Detachment (MCSSD)
Rifle Company	Combat Engineer Detachment	
Weapons Company		
Infantry Battalion		

Table 3. Force Module Entities

After forces are created and, if required, their default planning factors modified, the force is added to the SBLDSS Force List. The planner is then able to edit the forces on the Force List in the Force Manager Menu and view inventory reports for each force. Since the aviation combat element (ACE) is expected to be sea-based during OMFTS

operations, it remains sea-based for the SBLDSS. If the planner wishes to model the ACE ashore, logistics planning factors may be established using the methodology provided in this thesis.

2. Transporters

Transporters provide a critical link in the sea-based distribution system between the sea-base and the forces operating ashore. By reducing the logistical tail of large shore-based combat service support units, supply storage capacities of forces operating ashore are drastically decreased. This increases the risk associated with conducting combat operations with a constrained logistics system. As stated by LtGen P. Shutler, USMC (Ret.), "successful military operations depend on positioning a superior force to overcome the enemy threat with minimum loses to friendly units". [Ref. 2] Available transportation assets are required to move these forces, their supplies, and their equipment into tactically sound positions. These same transporters must provide sustainment, operational maneuver, and MEDEVAC support to these forces. Surface craft may be used for initially establishing units ashore. However, once inland, the combat units, with their mobile combat service support detachments, will not be expected to maintain logistical lines of communication with a beach support area. Instead, they will rely solely on aircraft for distribution functions.

The operating distances expected in the OMFTS and STOM Concepts (25 - 100 miles from ship-to-shore and up to 200 miles from shore-to-objective) are large. This makes aircraft survivability, availability, mission radius, and cargo capacity at these distances critical planning factors in determining the feasibility of the commander's

concept of operations ashore. Maximum distances exceed the MV-22's non-refueled mission radius of 200 nautical miles. [Ref. 14: p. 71] Even at the MV-22's maximum non-refueled mission radius, mobile combat service support detachments will not have the survivability or responsiveness to convoy from a beach support area, through potential enemy controlled areas, to resupply the supported combat units. For this reason, air transportation assets provide a critical link to sustaining combat units in the OMFTS, STOM, and SBL environment. The principal transportation assets modeled in the SBLDSS program for ship-to-shore movement include: the MV-22 Osprey, expected to begin fielding to Marine Corps units in 2005 and the CH-53E Super Stallion, currently in the Marine Corps inventory.

C. COMMODITY INVENTORY MODELS OVERVIEW

The SBLDSS predicts commodity levels of forces operating ashore based on the Events on the SBLDSS Event List and the passage of time. The expected amount of a certain commodity at a specific time depends on the initial commodity level of the force, the amount of the commodity consumed by the force, and the amount of the commodity delivered to the force. The basic commodity inventory model for forces operating ashore can be described with the following equation:

$$I_{s, f, t_l} = I_{s, f, t_b} - \sum_{t_b}^t consumed_{s, f} + \sum_{t_b}^t delivered_{s, f}$$

Where:

I_{s, f, t_l} = the inventory level of supply s in force f at end time t_l

I_{s, f, t_b} = the inventory level of supply s in force f at beginning time t_b

$\sum_{t_b}^t consumed_{s, f}$ = amount of supply s consumed in force f between t_b and t_l

$\sum_{t_b}^t delivered_{s, f}$ = amount of supply s delivered to force f between t_b and t_l

The class I subsistence, class III(W) bulk fuel, and class V(W) ground

ammunition commodity consumption models, used to determine the amount of supplies consumed, are based on passage of time and scheduled Events during the time window of interest. For example, a Movement to Contact Event will cause a force to consume ammunition and fuel based on the amount of ammunition the force is expected to expend and the movement duration of the Event. The reduction in the commodity level occurs when the Event is scheduled to take place on the Event List. The force's generators and material handling equipment may also consume fuel during this time period. This causes a further reduction of the fuel commodity level at the end of the time-period. The force's fuel level is increased by a Resupply Event modeling fuel being delivered to the force. Consumption models for each class of supply are discussed in the following sections.

D. CLASS I (FOOD AND WATER) CONSUMPTION

Class I (Food) consumption depends on the number of Marines in each Force Module. Since STOM operations are implicitly short term operations, MREs are the only

food planned for in this model. The amount of food each Force Module requires per day is determined using the following equation:

$$F_f = M_f \times CR_f \times CF$$

Where:

F_f = pounds of food force f requires per day

M_f = number of Marines in force f

CR_f = consumption rate (MREs per day) of force f , [Ref. 15]

CF = planning factor converting MREs to pounds (1.46 lbs per MRE), [Ref. 15]

Class I (water) consumption is computed in gallons per man per day for each Force Module. Adequate water sources and water purification units may not always satisfy daily demand requirements of Marine forces ashore during sea-based operations. In this case, water made from the sea-base would need to be transported to forces ashore. The model uses the four planning factors in Table 1, dependent on force size and temperature in the operating area, to predict daily water consumption of forces ashore.

Environmental Condition	Temperature Range (degrees Fahrenheit)	Planning Factor (gallons per man per day)
Extremely Cold (EC)	$-65 < T < 0$	10
Cold (C)	$0 < T < 32$	12
Normal (N)	$33 < T < 109$	15
Hot (H)	$T > 110$	24

Table 4. Water Consumption Planning Factors After [Ref. 12]

Water consumption is computed using the following equation:

$$W_f = M_f \times WCR_{f,c}$$

W_f = gallons of water consumed by force f per day

M_f = number of Marines in force f

$WCR_{f,c}$ = per day water consumption planning factor, in Table 4, of force f operating in environment c , [Ref. 12]

E. CLASS III(W) (BULK FUEL) CONSUMPTION

In a sea-based environment, both forces operating ashore and the vehicles and equipment used to support them contribute to overall fuel consumption. In this model, forces ashore are assumed to consume diesel fuel. Force fuel usage is predicted by either passage of time or by a specific Event. The first case, passage of time, occurs when forces have equipment, such as generators or material handling equipment, as part of their T/E. If a force has these types of equipment as part of their T/E, the model uses a daily fuel planning factor [Ref. 12] based on the typical number of hours each piece of equipment operates and the amount of fuel each piece of equipment consumes per hour. The consumption rate and hours of operation per day are then converted to gallons per day fuel consumption rates for each Force Module ashore. The equation below shows this relationship:

$$F_f = E_{n,f} * FCR_n * T$$

Where :

F_f = gallons of fuel consumed per day by force f

$E_{n,f}$ = number of equipment type n in use by force f , [Ref.15, 16]

FCR_n = fuel consumption rate of equipment n in gallons per hour, [Ref.12]

T = hours each day equipment type n is operated, [Ref.12]

In the model, the amount of fuel consumed per day causes a discrete reduction in the force's fuel inventory. The second case in which a force consumes fuel is during a move event. A move event occurs when a force uses vehicles assigned to their T/E to move for a specified duration. The equation below shows this relationship:

$$F_f = V_{n,f} * FCR_n * T$$

Where :

F_f = gallons of fuel consumed by force f during a move event

$V_{n,f}$ = number of vehicles of type n in the T/E of force f

FCR_n = fuel consumption rate of vehicle type n in gallons per minute

T = time in minutes for force to travel

Each move event causes a reduction in the Force Module's fuel inventory.

day or rounds per unit type per day. These planning factors, designed to determine war reserve stock, positioning, and transportation planning, do not provide the combat service support planner an accurate LPF. Modeling expenditure as rounds per weapon per day multiplied by the number of weapons ashore in a given threat scenario seems like a good way to forecast consumption rates and thus plan resupply missions. However, these LPFs do not account for periods of inactivity or periods with high operational tempo.

The SBLDSS models ammunition expenditure for Marine Forces ashore by accounting for the enemy threat environment, tempo of operations, expected expenditure over a period of time, and the Concept of Operations for the Marine Force.

1. Threat Environment

Marine Corps Order (MCO) 8010.1E [Ref. 13] provides LPFs for three different enemy threats in which Marines are expected to operate. These include infantry-heavy, armor-heavy, and composite planning factors by ammunition type in units of rounds per weapon per day and rounds per unit per day.

a. Infantry-Heavy Planning Factors

Infantry-heavy planning factors are based on a scenario involving a Marine Air-Ground Task Force (MAGTF) stopping the advance of an opposing force within an assigned sector; defending in place while forces are built up in the area of operations; and then conducting offensive operations. The opposing force is expected to be a regularly organized infantry-heavy combined arms army supported by modern air forces.

be a regularly organized infantry-heavy combined arms army supported by modern air forces.

b. Armor-Heavy Planning Factors

Armor-heavy planning factors are based on a scenario involving a MAGTF stopping the advance of an opposing force within an assigned sector; defending in place while forces are built up in the area of operations; and then conducting offensive operations, including an amphibious assault. The opposing force is a regularly organized armor-heavy combined arms army supported by modern air forces.

c. Composite Planning Factors

The composite planning factors were determined by using "weighted averages" of the LPFs from the two previous scenarios. [Ref. 13] These LPFs are used when planning class V(W) expenditure in an uncertain environment. The expected threat is primarily infantry, but may be reinforced by unknown forces.

2. Insignificant Ammunition

The SBLDSS determines the expected expenditure of Insignificant Ammunition, as defined here, over time by the current threat level and the size of each Marine element operating ashore. Insignificant Ammunition is ammunition required for mission accomplishment, but with a very low expenditure rate and overall weight. Examples include M9 pistol and sniper rifle ammunition. This type of ammunition is planned using the LPFs provided in MCO 8010.1E and the following equation:

$$A_i = \sum_j (Q_{ij} \times Y_i \times V_j \times T) \text{ for all Forces}$$

Where :

A_i = total daily ammunition type i requirement by the Marine element in pounds during period t

Q_{ij} = rounds per day of type i used by weapon type j , [Ref. 12]

Y_i = weight of ammunition type i round in pounds, [Ref. 12]

V_j = number of weapon type j in Marine element

T = time period of interest in days

3. Significant Ammunition

"Significant ammunition" is ammunition critical for mission accomplishment that has a high consumption rate and/or heavy overall weight. Examples include crew-served weapon and artillery ammunition. This type of ammunition is forecasted using aggregate consumption of certain Force Events, related to operational tasks, planned for the Marine elements ashore. The following Force Events, taken from the Army's Mission Training Plan (MTP) for the Infantry Rifle Company, [Ref. 15], are included in this part of the model: Movement to Contact, Attack, Raid, Withdraw, and Defend.

a. *Movement To Contact*

The Movement to Contact Event is used when the Marine element is planning to take combat action upon contact with the enemy in a known area. A typical situation when this is used includes when enemy contact has been broken, he has withdrawn deep, is being reinforced, and is preparing to counterattack near his last known

location. The Marine element is tasked with moving forward to establish contact with the enemy, destroying smaller sized units or fixing larger units in place.

b. Attack

The Attack Event is used when the Marine element is planning to attack and seize an objective. The element knows the enemy's location and plans to kill or capture the enemy, or force him to withdrawal.

c. Raid

The Raid Event is used when the Marine element is planning a raid on an unexpected enemy position. The element is expected to accomplish its assigned tasks without becoming decisively engaged.

d. Withdraw

The Withdraw Event is used when the Marine element is planning to conduct a delaying operation while withdrawing in the face of a superior enemy force. The element is expected to delay the enemy in a designated area for a specified period of time.

e. Ambush

The Ambush Event is used when a Marine element plans to ambush a known enemy force, mounted or dismounted, along lines of communication or natural lines of drift. The element is expected to surprise and engage the enemy and either kills or captures all enemy in the established kill zone.

f. Defend

The Defend Event is used when a Marine element is planning to repel an expected enemy force from a defensive position.

All Events assume the basic allowance (BA) of ammunition is established prior to the Event and the element has been reinforced with the necessary ammunition to perform the specific purpose of each Event during preparation. This requires the SBLDSS planner to either accept the BA already in the model or change it to reflect the amount required to complete the mission. Basic allowance of ammunition is defined as the amount of ammunition by type recommended to be carried within the means normally available to the Marine element [Ref 16]. BA established in MCO 8010.1E, in units of rounds per weapon, is used as default values in the model. Force Events effect each Force Module's class V(W) inventory as discrete events. The model assumes the Force Module will not consume more than 50% of its BA before breaking contact with the enemy. The expected amount of ammunition required for each Event is determined by the following equation:

$$A_i = (BA_i * Y_i * CPF) \text{ for each Force}$$

Where :

A_i = total expected amount of ammunition type i used in pounds

BA_i = rounds of type i in basic allowance, [Ref. 15]

Y_i = weight of ammunition type i round in pounds, [Ref. 15]

CPF = percentage of BA expected to consume during the combat event. Default value = 0.5.

G. TRANSPORTATION PLANNING

The Ship-to-Objective Delivery (STOD) transportation assets modeled in the SBLDSS include the MV22 and CH53E aircraft. Characteristics of each aircraft, along

with transportation planning factors, are used to model STOD capability to meet operational and logistic demand. The planner imposes a demand on the available transportation assets by creating Resupply, Move Force, and MEDEVAC Events, on the SBLDSS Event List. The planner is then able to model the desired number of MV22 and CH53E aircraft by creating each aircraft in the setup menu of the SBLDSS. Before the transportation asset is added to the Aircraft List, the planner is able to change any of its characteristics to reflect up-to-date status from current availability reports and known operating conditions.

1. MV22 Osprey

The MV-22 Osprey is a medium lift, vertical assault transport for troops, equipment, and supplies, and is designated to replace the CH-46 Sea Knight as the Marine Corps' aviation medium lift asset. A tiltrotor aircraft, the MV-22's improved range, speed, and payload is expected to provide a tremendous improvement in the Marine Corps' ability to project power from OTH towards inland objectives in STOM. The MV-22's extended combat radius will allow the Navy ships to maintain adequate stand-off distances from enemy shore-to-ship missiles and other developing threats while complicating the enemy's defense and inhibiting his ability to concentrate his forces. The MV-22, currently in the test and evaluation phase, is expected to be operational in the Marine Corps in 2014. Figure 12 shows the default characteristics as pictured in the MV22 setup window of the SBLDSS.

Create New MV22

Transporter Data

Tail Number:	1	Speed Data:	External 240 Internal 180	Availability and Opt Time:	<input checked="" type="radio"/> Available <input type="radio"/> Not Available Op Time: 0.0
Location:	0.0, 0.0	External 240 Internal 180	hours		
Inter-radius:	210.0	External 240 Internal 180	hours		
Endurance:	160.0	External 240 Internal 180	hours		

Max Internal Commodity Load Data

Food	3363.0	Water	11000.0
Water	11000.0	Food	11000.0
Fuel	11000.0	Water	6790.0
ammo	9800.0	Fuel	2200.0

Max External Commodity Load Data

Food	5046.0	Water	8100.0
Water	8100.0	Food	6790.0
Fuel	6790.0	Water	2200.0
ammo	2200.0	Fuel	

Distance vs. Internal Capacity Data

0 miles	11000.0	1000 miles	11000.0
1000 miles	10000.0	2000 miles	11000.0
2000 miles	9500.0	3000 miles	9000.0
3000 miles	5500.0	4000 miles	5500.0

Distance vs. External Capacity Data

0 miles	11000.0	1000 miles	11000.0
1000 miles	11000.0	2000 miles	11000.0
2000 miles	9000.0	3000 miles	9000.0
3000 miles	5500.0	4000 miles	5500.0

Category Data

PAK Capacity: 24	External Lift <input checked="" type="radio"/> Internal Lift <input type="radio"/> PAK <input type="radio"/> Others	Load PAK: 10 Load Internal: 20 Load External: 3 Load Others: 15
------------------	---	--

Accept Cancel

Figure 12: Example Create MV-22 Window

2. CH-53E Super Stallion

The CH-53E Super Stallion is the Marine Corps' premier heavy lift aviation asset.

A shipboard-compatible helicopter, the CH-53E is configured for lift and movement of cargo and passengers internally and external lift of heavy oversized equipment. CH-53E missions include tactical movement of heavy weapons and equipment and tactical resupply and insertion/extraction of Marine forces operating ashore. Figure 13 shows the default characteristics as pictured in the CH-53E setup window of the SBLDSS.

Create New CH53E

Transporter Data		Speed Data		Availability and On-time	
Cat Number	21	Internal Int.	150	Available	
Latitude	0.0, 0.0	External Int.	130	not available	
Altitude	240.0 miles			Opt Time	0.0
Altitude	240.0 miles				
Internal Community Load Data					
Food	6587.0 lbs	Food	7528.0 lbs		
Water	19929.0 gallons	Water	13950.0 gallons		
Med	16224.0 lbs	Med	11055.0 lbs		
ammo	15400.0 lbs	ammo	8800.0 lbs		
External Community Load Data					
Food	23500.0 lbs	Food	23500.0 lbs		
Water	20000.0 lbs	Water	22500.0 lbs		
Med	17500.0 lbs	Med	17000.0 lbs		
ammo	0.0 lbs	ammo	0.0 lbs		
Distance vs. External Capacity Data					
0 miles	23500.0 lbs				
100 miles	22500.0 lbs				
225 miles	17000.0 lbs				
7400 miles	0.0 lbs				
Load Data					
Load Intensity	37	Select Configuration		Time Factors	
<input type="radio"/> External LIFT		<input type="radio"/> Internal LIFT		Load DPA	10 minutes
<input checked="" type="radio"/> Internal LIFT		<input type="radio"/> PAK		Load Intensity	20 minutes
<input type="radio"/> PAK		<input type="radio"/> Lift		Load Factor	3 minutes
<input type="radio"/> Lift				Not Relieve	15 minutes
Accept Cancel					

Figure 13: Example Create CH-53E Window

3. Transportation Planning Considerations

Throughout the duration of a ground operation, many factors determine whether the commander's concept of operations can be feasibly supported using available aircraft. The effects of night operations, adverse weather, and enemy air defense diminish the ultimate performance of the transportation systems. Additionally, aircraft maintenance and aircrew flying constraints make planning even more difficult. This section discusses the planning factors considered when modeling transportation assignment and scheduling in the SBLDSS. Aircraft planning factors discussed include maximum sortie distance, mission load efficiency, aircraft availability, cycle time calculations, and possible mission sequencing.

a. Maximum Sortie Distance

The maximum sortie distance each Transporter can support forces is a function of the cargo load, time planning factors, fuel consumption rates, and environmental conditions. Using speed, distance, time, and consumption relationships, the maximum sortie distance for each Transporter type can be calculated. The SBLDSS uses a maximum sortie radius of 200 nautical miles for the MV-22 and 240 nautical miles for the CH-53E.

b. Mission Load Efficiency

The mission load requirement, whether Resupply, Force Move, or MEDEVAC missions, and the aircraft's cargo capacity determine Mission Load Efficiency.

$$\text{Efficiency} = \frac{\text{Payload}}{\text{MissionLoad}}$$

Where :

Payload = cargo capacity of the aircraft

MissionLoad = demand placed on Transporter assets based on mission requirement

Aircraft cargo capacity takes into account the type of mission, the type of cargo, and the amount of fuel reserve the aircraft crew desires upon return to the sea-base. The model distinguishes between wet and dry cargo capacities. Fuel and water delivery missions are assumed to be accomplished using 500 gallon fuel bladders and 250 gallon water bladders, respectively. Tables 5 and 6 show the MV-22 and CH-53E cargo profiles. In the SBLDSS the maximum weight allowed for the CH-53E is 23,500 pounds.

Supply Class	Quantity	Package	Unit Weight (lbs)	Maximum Weight (lbs)
Class I Food	4	Pallets internal	1,110	4,400
	6	Pallets external	1,110	6,660
Class I Water	5	250 gal bladders	2,325	11,625
Class III Fuel	3	500 gal bladders	3,685	11,055
Class V Ammo	4	Pallets internal	2,200	8,800
	1	Pallets external	2,200	2,200

Table 5. MV-22 Cargo Profile by Class of Supply After [Ref. 16]

Supply Class	Quantity	Package	Unit Weight (lbs)	Maximum Weight (lbs)
Class I Food	7	Pallets internal	1,110	7,700
	8	Pallets external	1,110	8,800
Class I Water	12	250 gal bladders	2,325	27,900
Class III Fuel	6	500 gal bladders	3,685	22,110
Class V Ammo	7	Pallets internal	2,200	15,400
	4	Pallets external	2,200	8,800

Table 6. CH-53E Cargo Profile by Class of Supply After [Ref. 16]

Aircraft cargo capacity is a function of maximum vertical takeoff weight, the residual weight of the crew and reserve fuel, and the amount of fuel needed to accomplish the mission at the location of the supported force. The equation below shows this relationship:

$$\text{Capacity} = \text{MVTOW} - \text{Resid} - \text{ReqFuel}$$

Capacity = cargo capacity of the aircraft

MVTOW = maximum vertical takeoff weight at operational temperature and altitude in lbs

Resid = residual weight of airframe, aircrew and reserve fuel in lbs

ReqFuel = fuel required to complete mission

As an example, the MV-22 has a maximum sortie radius of 200 nautical miles. The maximum amount of fuel the MV-22 can carry is 7,700 pounds. With an MVTOW of 50,887 pounds and a 37,687 pounds, the MV-22 has a payload capacity of 5,500 pounds.

c. Aircraft Availability

The SBLDSS does not model aircraft availability using typical availability calculations. Aircraft availability is typically modeled using a mission capable rate between zero and one, for example between 0.70 and 0.85, depending on the type of aircraft. This factor, determined through operational testing, is based on the expected number of aircraft available during a given day. The small number of aircraft on a sea-base magnifies the capabilities each aircraft provides to the ship-to-objective distribution network. For this reason, the planner must be aware of each aircraft's current availability status.

The planner is able to view the status of each aircraft on the Aircraft List that is found under the Aircraft Manager Menu. He can change an aircraft's availability as its status changes by editing the aircraft. By designating a transporter as unavailable during a given planning horizon, the planner is able to reflect the aircraft's current status on the

daily availability report. The planner can also model other operational taskings not already modeled as Transporter Events (for example, use as a command and control platform). The SBLDSS takes both the amount of time to the next scheduled maintenance check and the maximum daily crew operating limits into consideration as constraints when scheduling transportation sorties. If, due to the operation time accumulated during a sortie, the aircraft does not meet one of these constraints, the aircraft is then set as unavailable for that mission and for the remainder of the planning horizon.

The number of aircraft available for lift missions determines the total number of sorties available for mission planning. This determines the amount of troop and cargo throughput capacity, or maximum flow, from the ship to the objective, along the ship-to-objective distribution network.

d. Cycle Time Calculations

The total cycle time of each sortie determines the time when the aircraft will become available after it completes an assigned mission sequence. In the SBLDSS, an aircraft sortie may consist of either one or two Transporter Events. When modeling aircraft sorties, the SBLDSS considers the time to load and unload passengers, the time to load and unload both internal and external cargo, and the time to hot-refuel each aircraft. The total cycle time for each sortie is computed using the following equation:

$$TC_{t,s} = 2 \times T_s \times TLT_t + 2 \times R_s \times TLC_t + TRH_t$$

$TC_{t,s}$ = total cycle time in minutes of aircraft t on sortie s
 T_s = number of Move Force and MEDEVAC Events in sortie s
 R_s = number of Resupply Events in sortie s
 TLT_t = time to load/offload Marines for aircraft t
 TLC_t = time to load/offload cargo for aircraft t
 TRH_t = time to hot refuel aircraft t

Table 7 shows the time planning factors used in the SBLDSS.

Time Factor (minutes)	MV-22 Osprey	CH-53E
Load/unload troops	10	10
Load/unload internal cargo	20	20
Load/unload external cargo	3	3
Hot refuel at the Sea-base	15	15

Table 7. MV-22 and CH-53E Time Planning Factors After [Ref 16]

e. Mission Sequencing

Transporter Events in the SBLDSS model possible aircraft missions.

These missions are specifically modeled to demonstrate the necessity for sea-based transportation planning to include both operational and sustainment operations. Feasible mission combinations in each sortie include:

$\{R\}, \{T\}, \{M\},$
 $\{R, M\}, \{T, M\}, \{T, T\}$
OR
 $\{R, T\}$

Where :

R = Resupply Event
T = Move Force Event
M = MEDEVAC Event

4. Aircraft Scheduling Algorithm

The aircraft scheduling algorithm developed for the SBLDSS is a heuristic based on the Multiple Tour Maximum Collection Problem (MTMCP) as outlined in Naylor, [Ref 17]. The heuristic, written in Java 1.2 [Ref. 11], uses the König Java Class Library developed by MAJ Leroy A. Jackson of the TRADOC Analysis Center-Monterey (TRAC-Monterey). [Ref. 18] König is an application programmer interface (API) providing a set of graph and network objects and algorithms to model and solve network problems.

a. *Multiple Tour Maximum Collection Problem (MTMCP)*

The MTMCP consists of collecting the maximum reward from a subset of weighted nodes such that each tour is completed within a time constraint. A tour is defined as a sequence of mission nodes visited by the aircraft during one cycle. A tour provides a theoretical representation of an aircraft sortie with multiple aircraft missions. The weights on each node are determined by the measure of effectiveness the modeler wishes to maximize. The goal of the MTMCP algorithm is to gain the maximum value

from the nodes selected for a predefined number of tours. A distinct feature of the MTMCP is that the number of tours is fixed and not all nodes are visited.

b. SBLDSS Scheduling Heuristic Description

The SBLDSS scheduling heuristic differs from the MTMCP in that the number of tours are determined by the ability of an aircraft to accomplish a sequence of missions within time and distance constraints. The aircraft are constrained by cargo limitations based on distance, cargo, and fuel tradeoff as described in the previous section. The total cycle time of each tour must be less than the time until the available aircraft's next maintenance check and the maximum crew-operating limit. Each mission in the SBLDSS also has a time window in which the mission must be accomplished. Each node in the SBLDSS scheduling algorithm represents either an available aircraft modeled as an aircraft node or a sequence of missions, modeled as a mission node. An arc exists between an aircraft node and a mission node only if the aircraft can accomplish the mission sequence within these constraints. Figure 14 shows an example of the graphical representation of this node and arc relationship.

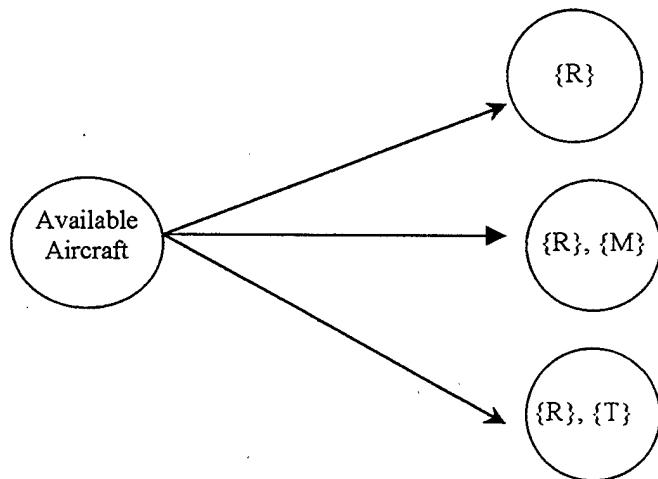


Figure 14: Example Arc-Node Representation

Each aircraft and mission node combination is designated a feasible tour and added to a tour list. Each mission node is given a weight determined by the efficiency of the Transporter accomplishing the mission and the distance from the sea-base to the mission objective location. A penalty is applied to the mission weight if the aircraft must loiter between two missions for over 30 minutes. The following equation shows how each mission node is weighted:

$$Wgt_j = D_{i,j} \times \frac{Payload_{i,j}}{MissionLoad_j} \times Penalty_{(loiter)}$$

Where:

- Wgt_j = the weight determined for mission node j
- $D_{i,j}$ = the distance the Transporter must travel from node i to node j
- $MissionLoad_j$ = the total lbs required to accomplish the sequence of missions at the mission node j
- $Payload_{i,j}$ = the cargo capacity potential of the transporter between nodes i and j
- $Penalty_{(loiter)}$ = a penalty for the time an aircraft loiters between missions in a two mission sequence

Each tour accumulates a reward, consisting of the sum of all the weighted mission nodes the Transporter is able to accomplish. Once all feasible tours are determined, they are sorted and ranked by highest reward first in a tour list. Once ranked, the Transporter associated with the tour having the highest reward is assigned a sortie consisting of the mission sequence associated with this tour. The residual for all missions in the mission sequence of the assigned sortie is computed using the following equation:

$$residual = Missionload_j - Payload_{i,j}$$

The tour list is then searched and all identical missions have their residuals updated to reflect the new residual. If the residual is equal to zero, each tour on the tour list with an identical mission is marked as completed. The operation time of the Transporter that accomplished the sortie is updated to reflect the additional time accumulated by completing the sortie. The next uncompleted tour on the tour list is now checked to see if the associated Transporter can accomplish the tour based on its new operational time and any sorties already scheduled. At this point, all constraints are checked, including the time to the Transporter's next scheduled maintenance check, the maximum allowed daily crew flying time, and the earliest and latest time window delivery requirement of each mission in the mission sequence of this next tour. If the tour is feasible, it becomes a sortie, it is added to the sortie list, and the Transporter's variables are updated. If not feasible, it is passed and the next tour is checked for feasibility. This procedure continues until all tours have been inspected for feasibility. The final sortie list provides a schedule for each Transporter sortie including a departure time from the sea-base, a delivery time at the mission objective, and a return time to the sea-base. A list of unaccomplished missions is displayed along with the reason for their unfeasibility to allow the planner to determine how he can relax the constraints to obtain a feasible sustainment solution. The total number of sorties and operational hours accumulated by each Transporter is also displayed to allow the planner to update this information if they choose the sustainment solution.

c. Scheduling Algorithm

The following section outlines the Scheduling heuristic developed for the SBLDSS.

- For each Transporter, create a simple Graph of all feasible single mission nodes. If the tour is feasible, assign the mission node a calculated weight.
- For each Graph, create an improved Graph of feasible single mission nodes and two mission sequence nodes. For each feasible tour, assign the tour a reward calculated by accumulating weights of all mission nodes in the tour.
- Create a tour list, consisting of all tours associated with all Graphs, sorted in rank order by highest reward.
- Create a sortie list by iterating through the tour list, determining feasible tours, updating Transporter operational calculations, and computing and updating all mission residuals on the tour list.
- Display the sortie list as a schedule for all Transporter sorties on the list.

V. MODEL APPLICATION

This chapter shows how the SBLDSS can be applied to a real-world planning environment by providing an illustrative scenario. In this scenario, the planners are using the SBLDSS as a planning tool to develop a feasible Course of Action to support the commander's mission statement and Concept of Operations. Since the SBLDSS is a sustainment-planning tool, the scenario begins immediately after the forces finish their ship-to-shore movement.

A. SITUATION

A deteriorating situation in a Third World nation threatens U.S. interests in the region. Security is required to provide stability to the government. CSS requirements must be delivered directly to each task force element. Intelligence estimates indicate an infantry threat. Daytime temperature is 88 degrees Fahrenheit.

B. TASK ORGANIZATION

One Rifle Company will be with command group Alpha ashore. A LAV detachment will provide screening support. The ACE, along with the majority of the CSSE, remains afloat to reduce the security requirements of an established CSSE and ACE ashore.

1. Forces Ashore

The force structure is shown below in Table 8.

Unit Description	Personnel
Command Element	20
A Company	182
LAV Det	50
Total	252

Table 8. Task Organization

2. Total Air Assets Available

The lift assets for this scenario assume a one-for-one swap between current numbers of CH-46E helicopters found in a typical MEU (SOC) and the MV-22 tilt-rotor aircraft.

- 12 - MV22 Osprey
- 4 - CH53E Super Stallion

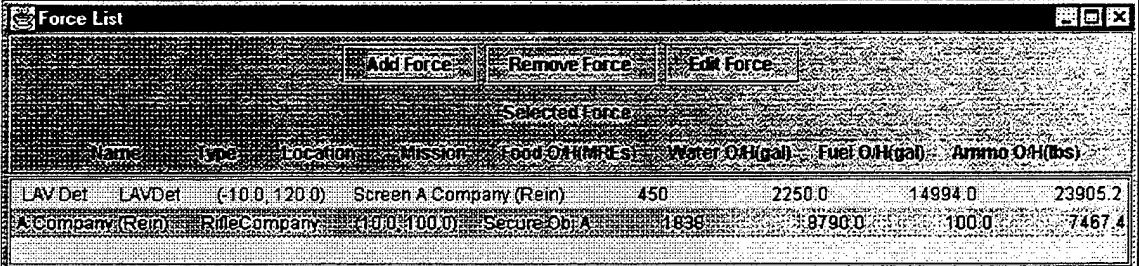
C. CONCEPT OF OPERATIONS

Establish a force ashore in order to provide a secure perimeter around objective A. Conduct the security operation until relieved. Class I, Class III, and Class V(W) sustainment will be provided directly from amphibious shipping to each security element. Routine situation reports will be provided daily along with immediate requests.

D. FORCE LIST

Figure 15 shows the Force List for this Course of Action as displayed in the SBLDSS. Command Group Alpha is co-located with A Company at coordinate (10, 100). This accounts for the size of A Company (Reinforced) being 202 instead of the 182 default value. The commodity consumption rates, basic allowances, and initial inventory levels have also been changed to reflect the LPFs associated with this larger force. The LAV Detachment, located at coordinate (-10, 120), has default LPFs to model commodity consumption, basic allowance, and initial inventory levels. Each force is

assumed to have matching initial inventory levels and basic allowances for each commodity.



The screenshot shows a software window titled "Force List". At the top, there are three buttons: "Add Force", "Remove Force", and "Edit Force". Below these buttons, the text "Selected Force" is displayed. The main area is a table with the following data:

Name	Type	Location	Mission	Fod O/H (MRE)	Water O/H (gall)	Fuel O/H (gal)	Ammo O/H (lbs)
LAV Det	LAVDet	(-10.0, 120.0)	Screen A Company (Rein)	450	2250.0	14994.0	23905.2
A Company (Rein)	Rifle Company	(10.0, 100.0)	Secure Obj A	1638	9790.0	100.0	7467.4

Figure 15: Force List

E. INITIAL REPORTS

The initial Commodity Inventory Reports, for each force in the Force List, are shown in Figures 16 and 17. These reports are generated once the planner develops the tasks for each force and models these tasks as Force Events. The planner uses the reports to anticipate resupply requests from the forces ashore. For example, the planner's objective is to maintain the commodity levels of each force at three days of supply (DOS) for every period over the report's 72 hours planning horizon. Since the planner will not be able to meet this goal, they will develop a resupply policy, or a trigger, for when a Resupply Event should be expected for each commodity. The planner first determines the amount of the commodity needed, along with the time the force requires resupply, and then adds Resupply Events to the Event List. This creates a demand that the Transportation Assets need to accomplish in the Scheduling Algorithm. Note that Figures 15 and 16 indicate no ammunition usage. This is because no Force Events are added to the Event List for either force. As the planner adds Force Events and Resupply Events to the Event List, they are able to view an updated Commodity Inventory Report

for each force. This ensures each commodity inventory level is met for every period in the planning horizon.

		272111ZAug99	280911ZAug99	282111ZAug99	290911ZAug99	292111ZAug99	302111ZAug99
3 DOS	Capacity	+0 Hours	+12 Hours	+24 Hours	+36 Hours	+48 Hours	+72 Hours
Food O/H (MREs)	1,818	1,638	1,535	1,232	929	626	20
Water O/H (gal)	8,790	8,190	8,790	7,325	5,860	4,395	2,930
Fuel O/H (gal)	100	100	100	93	86	79	72
Ammo O/H (lbs)	7,467	7,073	7,467	7,467	7,467	7,467	7,467

Figure 16: A Company (Rein) Commodity Inventory Report

		272111ZAug99	280911ZAug99	282111ZAug99	290911ZAug99	292111ZAug99	302111ZAug99
3 DOS	Capacity	+0 Hours	+12 Hours	+24 Hours	+36 Hours	+48 Hours	+72 Hours
Food O/H (MRES)	450	450	450	375	300	225	150
Water O/H (gal)	2,250	2,250	2,250	1,875	1,500	1,125	750
Fuel O/H (gal)	14,994	14,994	14,994	14,994	14,994	14,994	14,994
Ammo O/H (lbs)	23,905	23,905	23,905	23,905	23,905	23,905	23,905

Figure 17: LAV Detachment Commodity Inventory Report

F. EVENT LIST

Figure 18 shows the Event List, including both Force Events and Resupply Events, for A Company (Rein) and the LAV Detachment. These Events are placed in the SBLDSS to model specific tasks and emergent resupply requests of the forces ashore. As a reminder, since none of the Force Events are assigned a mission number in the Scheduling Algorithm, an “N/A” appears in the mission number column for all Force

Events. Also, "null" appears for all Transporter Events until the Scheduling Algorithm is executed.

Event List

Add Event Remove Event Edit Event

Selected Event: A Company (Rein); Resupply

	Mission #	DTG	Event Type	Time Window	Message
N/A	280530ZAug99	MvmtToContact	N/A N/A	LAV Det	
N/A	280600ZAug99	Defend	N/A N/A	A Company (Rein)	
null	280900ZAug99	resupply	280900ZAug99	281600ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo
null	280900ZAug99	resupply	280900ZAug99	281600ZAug99	Resupply A Company (Rein) 1465.0 gallons of water
null	280930ZAug99	resupply	280930ZAug99	281430ZAug99	Resupply LAV Det 7171.0 lbs of ammo
null	281230ZAug99	resupply	281230ZAug99	281600ZAug99	Resupply A Company (Rein) 606.0 MREs
N/A	281600ZAug99	MvmtToContact	N/A N/A	LAV Det	
N/A	281730ZAug99	Defend	N/A N/A	A Company (Rein)	
null	282000ZAug99	resupply	282000ZAug99	290500ZAug99	Resupply A Company (Rein) 1465.0 gallons of water
null	282030ZAug99	resupply	282030ZAug99	300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo
null	282030ZAug99	resupply	282030ZAug99	290900ZAug99	Resupply LAV Det 150.0 MREs
null	282030ZAug99	resupply	282030ZAug99	290900ZAug99	Resupply LAV Det 750.0 gallons of fuel
null	282030ZAug99	resupply	282030ZAug99	291100ZAug99	Resupply LAV Det 7171.0 lbs of ammo
null	282100ZAug99	resupply	282100ZAug99	290800ZAug99	Resupply LAV Det 750.0 gallons of water
N/A	290600ZAug99	Defend	N/A N/A	A Company (Rein)	
null	290700ZAug99	resupply	290700ZAug99	290900ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo
null	290930ZAug99	moveforce	290930ZAug99	291400ZAug99	Move 202 of A Company (Rein) from (100,100,0) to (200,140,0)
N/A	291200ZAug99	MvmtToContact	N/A N/A	LAV Det	
N/A	291330ZAug99	Attack	N/A N/A	A Company (Rein)	
null	291530ZAug99	resupply	291530ZAug99	300900ZAug99	Resupply LAV Det 7171.0 lbs of ammo
null	291600ZAug99	resupply	291600ZAug99	300500ZAug99	Resupply A Company (Rein) 3538.0 lbs of ammo
null	291600ZAug99	resupply	291600ZAug99	300800ZAug99	Resupply LAV Det 750.0 gallons of water
null	291600ZAug99	resupply	291600ZAug99	300900ZAug99	Resupply LAV Det 150.0 MREs
null	291630ZAug99	resupply	291630ZAug99	300900ZAug99	Resupply LAV Det 636.0 gallons of fuel
N/A	291700ZAug99	Defend	N/A N/A	A Company (Rein)	
null	292000ZAug99	resupply	292000ZAug99	300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo
null	292000ZAug99	resupply	292000ZAug99	300500ZAug99	Resupply A Company (Rein) 59.0 gallons of fuel
null	292000ZAug99	resupply	292000ZAug99	300500ZAug99	Resupply A Company (Rein) 2930.0 gallons of water
null	292000ZAug99	resupply	292000ZAug99	300500ZAug99	Resupply A Company (Rein) 606.0 MREs
null	292200ZAug99	resupply	292200ZAug99	300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo
N/A	300600ZAug99	Defend	N/A N/A	A Company (Rein)	
null	300800ZAug99	resupply	300800ZAug99	301600ZAug99	Resupply A Company (Rein) 3537.0 MREs
null	301000ZAug99	resupply	301000ZAug99	302330ZAug99	Resupply A Company (Rein) 2930.0 gallons of water
null	301000ZAug99	resupply	301000ZAug99	301600ZAug99	Resupply A Company (Rein) 606.0 MREs
N/A	301100ZAug99	MvmtToContact	N/A N/A	LAV Det	
null	301600ZAug99	resupply	301600ZAug99	302300ZAug99	Resupply LAV Det 150.0 MREs
null	301600ZAug99	resupply	301600ZAug99	302300ZAug99	Resupply LAV Det 630.0 gallons of fuel
null	301600ZAug99	resupply	301600ZAug99	302330ZAug99	Resupply LAV Det 7171.0 lbs of ammo
null	301630ZAug99	resupply	301630ZAug99	302300ZAug99	Resupply LAV Det 750.0 gallons of water
N/A	301730ZAug99	Defend	N/A N/A	A Company (Rein)	
null	302000ZAug99	resupply	302000ZAug99	010500ZSep99	Resupply A Company (Rein) 3536.0 lbs of ammo

Figure 18: Event List for A Company (Rein) and the LAV Det

G. UPDATED COMMODITY INVENTORY REPORTS

As the planner adds Resupply Events to the Event List, they are able to view an updated Commodity Inventory Report for each force. This allows the planner to ensure each force has the required commodity inventory level and that the transportation assets are properly tasked. Figures 19 and 20 show the final Commodity Inventory Reports for each force in the Force List, as seen in the SBLDSS. In this case, the planner decided to plan for only one food and one water resupply mission each day to fill the food and water requirements of each force, regardless of the 3 DOS goal. This is done to ensure increased aircraft sortie efficiency for the transportation assets. For this reason, food and water commodities are not maintained at each force's carrying capacity for each time in the planning horizon. Fuel is not critical for A Company (Rein) survivability, so it is only delivered once over the entire planning horizon. Conversely, fuel is critical for the

		272111ZAug99	280911ZAug99	282111ZAug99	290911ZAug99	292111ZAug99	302111ZAug99	
3 DOS	Capacity	+0 Hours	+12 Hours	+24 Hours	+36 Hours	+48 Hours	+72 Hours	
Food O/H (MREs)	1,838	1,838	1,535	1,838	1,535	1,838	5,375	
Water O/H (gal)	8,790	8,790	8,790	8,790	7,325	8,790	8,790	
Fuel O/H (gal)	100	100	100	93	86	79	100	86
Ammo O/H (lbs)	7,467	7,467	7,467	7,466	7,465	7,464	7,465	7,463

Figure 19: Updated Commodity Inventory Report for A Company (Rein)

		272111ZAug99	280811ZAug99	282111ZAug99	290911ZAug99	292111ZAug99	302111ZAug99
3 DOS	Capacity	+0 Hours	+12 Hours	+24 Hours	+36 Hours	+48 Hours	+72 Hours
Food O/H (MREs)	450	450	375	450	375	450	450
Water O/H (gal)	2,250	2,250	1,875	2,250	1,875	2,250	2,250
Fuel O/H (gal)	14,994	14,994	14,490	14,736	14,736	14,994	14,994
Ammo O/H (lbs)	23,905	23,905	23,905	23,905	23,905	23,905	23,905

Figure 20: Updated Commodity Inventory Report for LAV Det

LAV Det, so the planner has more routine fuel resupply missions planned for this force.

Note the ammunition levels in Figures 19 and 20 only fluctuate by a small amount, even though there are several Force Events involving ammunition consumption in Figure 18. This small fluctuation occurs because the planner realizes the emergent resupply needs of each force and adds emergent Resupply Events on the Event List. Ammunition is a logistics driver for each force because it is critical for each force to have adequate ammunition whenever they engage the enemy. Therefore, the planner must plan ammunition resupply missions to maintain as close to a 3 DOS level of ammunition as possible.

H. SCHEDULER OUTPUT

After the planner establishes a commodity resupply plan for each force ashore, they are able to see if they have enough available transportation assets to feasibly support the Course of Action. The available aircraft for this scenario are shown in Figure 21. This list shows four MV-22s and one CH-53E as being unavailable. Two MV-22s and the CH-53E are expected to be in scheduled maintenance. One MV-22 is planned for a

deception operation to draw attention away from the forces operating ashore. The last unavailable MV-22 will be used as a command and control platform for the MEU Commander.

Selected Transporter MV22, 5					
Tail#	Type	Op Hrs	Maint	Check	Crew Limit Available
1	MV22	1895.0	1925.0	8.0	no
2	MV22	1234.0	1275.0	8.0	no
3	MV22	1490.0	1525.0	8.0	no
4	MV22	4959.0	5000.0	8.0	no
5	MV22	5925.0	5975.0	8.0	yes
6	MV22	1520.0	1550.0	8.0	yes
7	MV22	1223.0	1250.0	8.0	yes
8	MV22	3550.0	3600.0	8.0	yes
9	MV22	5675.0	5725.0	8.0	yes
10	MV22	4553.0	4600.0	8.0	yes
11	MV22	3113.0	3150.0	8.0	yes
12	MV22	1342.0	1375.0	8.0	yes
21	CH53E	34526.0	34575.0	8.0	no
22	CH53E	303446.0	303475.0	8.0	yes
23	CH53E	304321.0	304350.0	8.0	yes
24	CH53E	65567.0	65600.0	8.0	yes

Figure 21: Initial Aircraft List

Figures 22, 23, and 24 show the scheduler output for the first day based on the Event List and the available aircraft in the Initial Aircraft List. Figures 22 and 23 show mission-to-aircraft combinations from the Aircraft Scheduling Algorithm. These two windows allow the planner to see the missions assigned to each aircraft by tail number. The scheduler computes and displays the departure time, time on station (TOS)/ time on

target (TOT), and return time for each mission based on the user's time window input for each Transporter Event.

Mission #	Depart Time	TOS/TOT	Return Time	A/C Type	A/C Tail Num	Remarks
1100	272111ZAug99	272211ZAug99	272336ZAug99	CH53E	22	resupply, LAV Det (-10.0, 120.0) Mission: 1100, residual = 0 lbs
300	272111ZAug99	272201ZAug99	272316ZAug99	CH53E	23	resupply, A Company (Rein) (10.0, 100.0) Mission: 300, residual = 0 lbs
900	272111ZAug99	272144ZAug99	272241ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 900, residual = 0 lbs
300	272111ZAug99	272144ZAug99	272241ZAug99	MV22	7	resupply, A Company (Rein) (10.0, 100.0) Mission: 300, residual = 0 lbs
1200	272111ZAug99	272151ZAug99	272256ZAug99	MV22	8	resupply, LAV Det (-10.0, 120.0) Mission: 1200, residual = 0 lbs
100	280551ZAug99	280630ZAug99	280732ZAug99	MV22	6	medevac, A Company (Rein) (10.0, 100.0) Mission: 100, residual = 0 lbs
200	280826ZAug99	280900ZAug99	280957ZAug99	MV22	8	resupply, A Company (Rein) (10.0, 100.0) Mission: 200, residual = 0 lbs
400	280849ZAug99	280930ZAug99	281034ZAug99	MV22	9	resupply, LAV Det (-10.0, 120.0) Mission: 400, residual = 0 lbs
400	280849ZAug99	280930ZAug99	281034ZAug99	MV22	10	resupply, LAV Det (-10.0, 120.0) Mission: 400, residual = 0 lbs
400	280849ZAug99	280930ZAug99	281034ZAug99	MV22	11	resupply, LAV Det (-10.0, 120.0) Mission: 400, residual = 0 lbs
400	281003ZAug99	281043ZAug99	281148ZAug99	MV22	8	resupply, LAV Det (-10.0, 120.0) Mission: 400, residual = 0 lbs
500	281156ZAug99	281230ZAug99	281327ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 500, residual = 0 lbs

Figure 22: First Window of First Scheduler Output

Mission #	Depart Time	TOS/TOT	Return Time	A/C Type	A/C Tail Num	Remarks
400	281003ZAug99	281043ZAug99	281148ZAug99	MV22	8	resupply, LAV Det (-10.0, 120.0) Mission: 400, residual = 0 lbs
500	281156ZAug99	281230ZAug99	281327ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 500, residual = 0 lbs
200	281333ZAug99	281406ZAug99	281504ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 200, residual = 0 lbs
800	281510ZAug99	281544ZAug99	281641ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 800, residual = 0 lbs
600	281554ZAug99	281700ZAug99	281829ZAug99	CH53E	24	medevac, LAV Det (-10.0, 120.0) Mission: 600, residual = 0 lbs
1200	281647ZAug99	281727ZAug99	281832ZAug99	MV22	5	resupply, LAV Det (-10.0, 120.0) Mission: 1200, residual = 0 lbs
700	281704ZAug99	281800ZAug99	281919ZAug99	CH53E	23	medevac, A Company (Rein) (10.0, 100.0) Mission: 700, residual = 0 lbs
800	281925ZAug99	282016ZAug99	282130ZAug99	CH53E	23	resupply, A Company (Rein) (10.0, 100.0) Mission: 800, residual = 0 lbs
1000	281929ZAug99	282030ZAug99	282154ZAug99	CH53E	22	resupply, LAV Det (-10.0, 120.0) Mission: 1000, residual = 0 lbs
1200	281949ZAug99	282030ZAug99	282134ZAug99	MV22	12	resupply, LAV Det (-10.0, 120.0) Mission: 1200, residual = 0 lbs
1300	282019ZAug99	282100ZAug99	282204ZAug99	MV22	7	resupply, LAV Det (-10.0, 120.0) Mission: 1300, residual = 0 lbs
1200	282140ZAug99	282221ZAug99	282325ZAug99	MV22	12	resupply, LAV Det (-10.0, 120.0) Mission: 1200, residual = 0 lbs
1300	282200ZAug99	282301ZAug99	290025ZAug99	CH53E	22	resupply, LAV Det (-10.0, 120.0)

Figure 23: Second Window of First Scheduler Output

The scheduler provides a feasible schedule for the first 24-hour transportation-planning horizon. In this case, the number of available aircraft for this planning horizon is sufficient to accomplish all missions within each associated Transporter Event's time window. Figure 24 shows the number of operating hours and the number of sorties accumulated by each aircraft over the first 24-hour transportation-planning horizon based on the scheduling algorithm.

Schedule for time beginning 272111ZAug99		
All missions were completed.		
Maximum Total Number of MV22 Sorties Required: 24 OR Maximum Total Number of CH53E Sorties Required: 24		
Tail Number	Accumulated op time	Total sorties
MV22, 1	0	0
MV22, 2	0	0
MV22, 3	0	0
MV22, 4	0	0
MV22, 5	7.817	5
MV22, 6	1.683	1
MV22, 7	4.783	3
MV22, 8	5.017	3
MV22, 9	1.75	1
MV22, 10	1.75	1
MV22, 11	1.75	1
MV22, 12	3.5	2
CH53E, 21	0	0
CH53E, 22	7.25	3
CH53E, 23	6.417	3
CH53E, 24	2.583	1

Figure 24: Third Window of First Scheduler Output

Since the planner has a feasible solution, he updates the accumulated operation time for each aircraft, from Figure 24, and solves the scheduler for the next 24 hour planning horizon. Figure 25 shows this updated aircraft list, used to solve for the second 24-hour transportation-planning horizon.

Transporter List

Add Transporter Remove Transporter Edit Transporter

Selected Transporter: CH53E, 24

Tail#	Type	Op Hrs	Maint	Check	Crew	Limit	Available
1	MV22	1895.0	1925.0		8.0		no
2	MV22	1234.0	1275.0		8.0		no
3	MV22	1490.0	1525.0		8.0		no
4	MV22	4959.0	5000.0		8.0		no
5	MV22	5929.8	5975.0		8.0		yes
6	MV22	1524.6	1550.0		8.0		yes
7	MV22	1227.8	1250.0		8.0		yes
8	MV22	3551.8	3600.0		8.0		yes
9	MV22	5676.8	5725.0		8.0		yes
10	MV22	4554.8	4600.0		8.0		yes
11	MV22	3114.8	3150.0		8.0		yes
12	MV22	1343.8	1375.0		8.0		yes
21	CH53E	34526.0	34575.0		8.0		no
22	CH53E	303453.3	303475.0		8.0		yes
23	CH53E	304323.1	304350.0		8.0		yes
24	CH53E	65573.9	65600.0		8.0		yes

Figure 25: Updated Aircraft List

Figures 26 and 27 show the first two windows of the scheduler output for the Transporter Events in the second 24-hour transportation-planning horizon. These figures provide the planner similar information to that shown in Figures 22 and 23.

Mission #	Depart Time	TOS/TOT	Return Time	A/C Type	A/C Tail Num	Remarks
700	272111ZAug99	272211ZAug99	272336ZAug99	CH53E	22	resupply, LAV Det (-10.0, 120.0) Mission: 700, residual = 0 lbs
1100	272111ZAug99	272201ZAug99	272316ZAug99	CH53E	23	resupply, A Company (Rein) (10.0, 100.0) Mission: 1100, residual = 0 lbs
1100	272111ZAug99	272144ZAug99	272241ZAug99	MV22	5	resupply, A Company (Rein) (10.0, 100.0) Mission: 1100, residual = 0 lbs
1300	272111ZAug99	272201ZAug99	272316ZAug99	CH53E	24	resupply, A Company (Rein) (10.0, 100.0) Mission: 1300, residual = 0 lbs
500	272111ZAug99	272151ZAug99	272256ZAug99	MV22	9	resupply, LAV Det (-10.0, 120.0) Mission: 500, residual = 0 lbs
500	272111ZAug99	272151ZAug99	272256ZAug99	MV22	10	resupply, LAV Det (-10.0, 120.0) Mission: 500, residual = 0 lbs
1300	272111ZAug99	272144ZAug99	272241ZAug99	MV22	6	resupply, A Company (Rein) (10.0, 100.0) Mission: 1300, residual = 0 lbs
100	280626ZAug99	280700ZAug99	280757ZAug99	MV22	7	resupply, A Company (Rein) (10.0, 100.0) Mission: 100, residual = 0 lbs
100	280626ZAug99	280700ZAug99	280757ZAug99	MV22	8	resupply, A Company (Rein) (10.0, 100.0) Mission: 100, residual = 0 lbs
300	281154ZAug99	281300ZAug99	281429ZAug99	CH53E	24	medevac, LAV Det (-10.0, 120.0) Mission: 300, residual = 0 lbs
400	281321ZAug99	281400ZAug99	281502ZAug99	MV22	6	medevac, A Company (Rein) (10.0, 100.0) Mission: 400, residual = 0 lbs
500	281435ZAug99	281536ZAug99	281700ZAug99	CH53E	24	resupply, LAV Det (-10.0, 120.0)

Figure 26: First Window of Second Scheduler Output

Schedule for time beginning 272111ZAug99						
800	281459ZAug99	281600ZAug99	281724ZAug99	CH53E	22	Mission: 500, residual = 0 lbs resupply, LAV Det (-10.0, 120.0)
500	281508ZAug99	281548ZAug99	281653ZAug99	MV22	6	Mission: 800, residual = 0 lbs resupply, LAV Det (-10.0, 120.0)
1000	281721ZAug99	281800ZAug99	281902ZAug99	MV22	5	Mission: 500, residual = 0 lbs medevac, A Company (Rein) (10.0, 100.0)
900	281730ZAug99	281831ZAug99	281955ZAug99	CH53E	22	Mission: 1000, residual = 0 lbs resupply, LAV Det (-10.0, 120.0)
700	281908ZAug99	281948ZAug99	282053ZAug99	MV22	5	Mission: 900, residual = 0 lbs resupply, LAV Det (-10.0, 120.0)
1200	281909ZAug99	282000ZAug99	282114ZAug99	CH53E	23	Mission: 700, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
1300	281926ZAug99	282000ZAug99	282057ZAug99	MV22	11	Mission: 1200, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
1300	281926ZAug99	282000ZAug99	282057ZAug99	MV22	12	Mission: 1300, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
1400	282120ZAug99	282211ZAug99	282325ZAug99	CH53E	23	Mission: 1300, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
1500	282126ZAug99	282200ZAug99	282257ZAug99	MV22	9	Mission: 1400, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
1500	282126ZAug99	282200ZAug99	282257ZAug99	MV22	10	Mission: 1500, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)
600	282303ZAug99	282337ZAug99	290034ZAug99	MV22	9	Mission: 1500, residual = 0 lbs resupply, A Company (Rein) (10.0, 100.0)

Figure 27: Second Window of Second Scheduler Output

Figure 28 shows the updated Event List associated with the scheduler output for this transportation-planning horizon. Notice how the scheduler assigns mission numbers in the updated Event List to match the same missions displayed in the scheduler output.

Event List					
		Add Event		Remove Event	
		Edit Event			
Selected Event: LAV Det, resupply					
Mission #	DTG	Event Type	Time Window	Message	
N/A 290600ZAug99	Defend	N/A N/A A Company (Rein)			
100 290700ZAug99	resupply	290700ZAug99 290900ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
200 290930ZAug99	moveforce	290930ZAug99 291400ZAug99	Move 202 of A Company (Rein) from (10.0,100.0) to (20.0,140.0)		
N/A 291200ZAug99	MvmtToContact	N/A N/A LAV Det			
300 291300ZAug99	medevac	291300ZAug99 291330ZAug99	MEDEVAC 5 from LAV Det at (-10.0,120.0)		
N/A 291330ZAug99	Attack	N/A N/A A Company (Rein)			
400 291400ZAug99	medevac	291400ZAug99 291430ZAug99	MEDEVAC 12 from A Company (Rein) at (10.0,100.0)		
500 291530ZAug99	resupply	291530ZAug99 300900ZAug99	Resupply LAV Det 7171.0 lbs of ammo		
600 291600ZAug99	resupply	291600ZAug99 300500ZAug99	Resupply A Company (Rein) 3538.0 lbs of ammo		
700 291600ZAug99	resupply	291600ZAug99 300800ZAug99	Resupply LAV Det 750.0 gallons of water		
800 291600ZAug99	resupply	291600ZAug99 300900ZAug99	Resupply LAV Det 150.0 MREs		
900 291630ZAug99	resupply	291630ZAug99 300900ZAug99	Resupply LAV Det 636.0 gallons of fuel		
N/A 291700ZAug99	Defend	N/A N/A A Company (Rein)			
1000 291800ZAug99	medevac	291800ZAug99 291830ZAug99	MEDEVAC 10 from A Company (Rein) at (10.0,100.0)		
1100 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
1200 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 59.0 gallons of fuel		
1300 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 2930.0 gallons of water		
1400 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 606.0 MREs		
1500 292200ZAug99	resupply	292200ZAug99 300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
N/A 300600ZAug99	Defend	N/A N/A A Company (Rein)			

Figure 28: Updated Event List for Second 24 Hour Planning Horizon

After inspecting Figures 26, 27, and 28, the planner is able to see that the scheduler provides an infeasible solution for the second 24-hour transportation-planning horizon. Mission 200, a Move Force Event relocating A Company (Rein) from location (10, 100) to (20, 140), is not accomplished. In this case, the available aircraft were not sufficient to accomplish all aircraft missions. Figure 29, the fourth window of the third scheduler output, shows the accumulated operating hours and sorties associated with this

aircraft schedule. The four MV-22's and one CH-53E, designated as unavailable by the planner, are not assigned mission sorties by the scheduler.

Schedule for time beginning 272111ZAug99		
Maximum Total Number of MV22 Sorties Required: 35		
OR		
Maximum Total Number of CH53E Sorties Required: 35		
Tail Number	Accumulated op time	Total sorties
MV22, 1	0	0
MV22, 2	0	0
MV22, 3	0	0
MV22, 4	0	0
MV22, 5	4.95	3
MV22, 6	4.95	3
MV22, 7	1.517	1
MV22, 8	1.517	1
MV22, 9	4.783	3
MV22, 10	4.783	3
MV22, 11	1.517	1
MV22, 12	1.517	1
CH53E, 21	0	0
CH53E, 22	7.25	3
CH53E, 23	6.25	3
CH53E, 24	7.083	3

Figure 29: Third Window of Second Scheduler Output

To get a feasible schedule, the planner could either make more aircraft available or change the time windows of the Resupply Events on the Event List. More aircraft could be made available by either finishing maintenance early or reallocating aircraft from other operational missions to the missions on the Event List. The planner could change the Resupply Event time windows by selecting them on the Updated Event List. To solve this infeasible schedule, the planner chooses to see how making more aircraft available effects the scheduler solution. The three aircraft in maintenance and the aircraft reserved for the decoy operation are made available by selecting each of these aircraft in the Updated Aircraft Window, Figure 25, selecting the "Edit Transporter" button, and

selecting the "available" checkbox in the Edit Transporter Window. Figure 30 shows the updated aircraft list with all aircraft available except the one MV-22 being used as a command and control platform.

Tail#	Type	Op Hrs	Maint	Check	Crew	Limit	Available
1	MV22	1895.0	1925.0		8.0		no
2	MV22	1234.0	1275.0		8.0		yes
3	MV22	1490.0	1525.0		8.0		yes
4	MV22	4959.0	5000.0		8.0		yes
5	MV22	5929.8	5975.0		8.0		yes
6	MV22	1524.6	1550.0		8.0		yes
7	MV22	1227.8	1250.0		8.0		yes
8	MV22	3551.8	3600.0		8.0		yes
9	MV22	5676.8	5725.0		8.0		yes
10	MV22	4554.8	4600.0		8.0		yes
11	MV22	3114.8	3150.0		8.0		yes
12	MV22	1343.8	1375.0		8.0		yes
21	CH53E	34526.0	34575.0		8.0		yes
22	CH53E	303453.3	303475.0		8.0		yes
23	CH53E	304323.1	304350.0		8.0		yes
24	CH53E	65573.9	65600.0		8.0		yes

Figure 30: Updated Aircraft List

Once the planner makes this change, they are able to re-solve the scheduler to see if a feasible distribution plan exists. Figures 31, 32 and 33 show the first three windows of

the updated scheduler output.

Schedule for time beginning 272111ZAug99						
Mission #	Depart Time	TOS/TOT	Return Time	A/C Type	A/C Tail Num	Remarks
900	272111ZAug99	272211ZAug99	272336ZAug99	CH53E	21	resupply, LAV Det (-10.0, 120.0) Mission: 900, residual = 0 lbs
700	272111ZAug99	272211ZAug99	272336ZAug99	CH53E	22	resupply, LAV Det (-10.0, 120.0) Mission: 700, residual = 0 lbs
1300	272111ZAug99	272221ZAug99	272357ZAug99	CH53E	23	resupply, A Company (Rein) (20.0, 140.0) Mission: 1300, residual = 0 lbs
500	272111ZAug99	272151ZAug99	272256ZAug99	MV22	2	resupply, LAV Det (-10.0, 120.0) Mission: 500, residual = 0 lbs
1300	272111ZAug99	272158ZAug99	272310ZAug99	MV22	3	resupply, A Company (Rein) (20.0, 140.0) Mission: 1300, residual = 0 lbs
1300	272111ZAug99	272158ZAug99	272310ZAug99	MV22	6	resupply, A Company (Rein) (20.0, 140.0) Mission: 1300, residual = 0 lbs
200	272111ZAug99	272203ZAug99	272320ZAug99	MV22	7	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
100	280612ZAug99	280700ZAug99	280811ZAug99	MV22	4	resupply, A Company (Rein) (20.0, 140.0) Mission: 100, residual = 0 lbs
100	280612ZAug99	280700ZAug99	280811ZAug99	MV22	5	resupply, A Company (Rein) (20.0, 140.0) Mission: 100, residual = 0 lbs
200	280837ZAug99	280930ZAug99	281046ZAug99	MV22	9	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	280837ZAug99	280930ZAug99	281046ZAug99	MV22	10	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	280837ZAug99	280930ZAug99	281046ZAug99	MV22	11	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs

Figure 31: First Window of Third Scheduler Output

Schedule for time beginning 272111ZAug99						
Mission #	Depart Time	TOS/TOT	Return Time	A/C Type	A/C Tail Num	Remarks
200	280837ZAug99	280930ZAug99	281046ZAug99	MV22	12	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	281052ZAug99	281145ZAug99	281301ZAug99	MV22	9	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	281052ZAug99	281145ZAug99	281301ZAug99	MV22	10	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	281052ZAug99	281145ZAug99	281301ZAug99	MV22	11	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
200	281052ZAug99	281145ZAug99	281301ZAug99	MV22	12	moveforce, A Company (Rein) (20.0, 140.0) Mission: 200, residual = 0 lbs
300	281154ZAug99	281300ZAug99	281429ZAug99	CH53E	23	medevac, LAV Det (-10.0, 120.0) Mission: 300, residual = 0 lbs
400	281307ZAug99	281400ZAug99	281516ZAug99	MV22	2	medevac, A Company (Rein) (20.0, 140.0) Mission: 400, residual = 0 lbs
500	281435ZAug99	281536ZAug99	281700ZAug99	CH53E	23	resupply, LAV Det (-10.0, 120.0) Mission: 500, residual = 0 lbs
800	281459ZAug99	281600ZAug99	281724ZAug99	CH53E	21	resupply, LAV Det (-10.0, 120.0) Mission: 800, residual = 0 lbs
700	281519ZAug99	281600ZAug99	281704ZAug99	MV22	3	resupply, LAV Det (-10.0, 120.0) Mission: 700, residual = 0 lbs
600	281522ZAug99	281610ZAug99	281721ZAug99	MV22	2	resupply, A Company (Rein) (20.0, 140.0) Mission: 600, residual = 0 lbs
1000	281644ZAug99	281800ZAug99	281940ZAug99	CH53E	24	medevac, A Company (Rein) (20.0, 140.0) Mission: 1000, residual = 0 lbs
500	281710ZAug99	281751ZAug99	281855ZAug99	MV22	3	resupply, LAV Det (-10.0, 120.0)

Figure 32: Second Window of Third Scheduler Output

Schedule for time beginning 272111ZAug99						
1300	281727ZAug99	281815ZAug99	281926ZAug99	MV22	2	resupply, A Company (Rein) (20.0, 140.0) Mission: 1300, residual = 0 lbs
600	281730ZAug99	281841ZAug99	282016ZAug99	CH53E	21	resupply, A Company (Rein) (20.0, 140.0) Mission: 600, residual = 0 lbs
1200	281849ZAug99	282000ZAug99	282135ZAug99	CH53E	22	resupply, A Company (Rein) (20.0, 140.0) Mission: 1200, residual = 0 lbs
1100	281912ZAug99	282000ZAug99	282111ZAug99	MV22	6	resupply, A Company (Rein) (20.0, 140.0) Mission: 1100, residual = 0 lbs
1100	281946ZAug99	282057ZAug99	282232ZAug99	CH53E	24	resupply, A Company (Rein) (20.0, 140.0) Mission: 1100, residual = 0 lbs
1500	282112ZAug99	282200ZAug99	282311ZAug99	MV22	7	resupply, A Company (Rein) (20.0, 140.0) Mission: 1500, residual = 0 lbs
1500	282112ZAug99	282200ZAug99	282311ZAug99	MV22	8	resupply, A Company (Rein) (20.0, 140.0) Mission: 1500, residual = 0 lbs
500	282117ZAug99	282157ZAug99	282302ZAug99	MV22	6	resupply, LAV Det (-10.0, 120.0) Mission: 500, residual = 0 lbs
1400	282141ZAug99	282252ZAug99	290027ZAug99	CH53E	22	resupply, A Company (Rein) (20.0, 140.0) Mission: 1400, residual = 0 lbs
1300	282317ZAug99	290005ZAug99	290116ZAug99	MV22	7	resupply, A Company (Rein) (20.0, 140.0) Mission: 1300, residual = 0 lbs

Figure 33: Third Window of Third Scheduler Output

Figure 34 shows the Updated Event List associated with this scheduler output. As the planner can see by inspecting Figures 31 through 34, this scheduler output provides a feasible aircraft sortie schedule for the second 24-hour transportation-planning horizon.

Event List					
Selected Event: A Company (Rein), resupply					
Mission #	DTG	Event Type	Time Window	Message	
N/A 290600ZAug99	Defend	N/A N/A	A Company (Rein)		
100 290700ZAug99	resupply	290700ZAug99 290900ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
200 290930ZAug99	moveforce	290930ZAug99 291400ZAug99	Move 202 of A Company (Rein) from (20.0,140.0) to (20.0,140.0)		
N/A 291200ZAug99	MvmtToContact	N/A N/A	LAV Det		
300 291300ZAug99	medevac	291300ZAug99 291330ZAug99	MEDEVAC 5 from LAV Det at (-10.0,120.0)		
N/A 291330ZAug99	Attack	N/A N/A	A Company (Rein)		
400 291400ZAug99	medevac	291400ZAug99 291430ZAug99	MEDEVAC 12 from A Company (Rein) at (20.0,140.0)		
500 291530ZAug99	resupply	291530ZAug99 300900ZAug99	Resupply LAV Det 7171.0 lbs of ammo		
600 291600ZAug99	resupply	291600ZAug99 300500ZAug99	Resupply A Company (Rein) 3538.0 lbs of ammo		
700 291600ZAug99	resupply	291600ZAug99 300800ZAug99	Resupply LAV Det 750.0 gallons of water		
800 291600ZAug99	resupply	291600ZAug99 300900ZAug99	Resupply LAV Det 150.0 MREs		
900 291630ZAug99	resupply	291630ZAug99 300900ZAug99	Resupply LAV Det 636.0 gallons of fuel		
N/A 291700ZAug99	Defend	N/A N/A	A Company (Rein)		
1000 291800ZAug99	medevac	291800ZAug99 291830ZAug99	MEDEVAC 10 from A Company (Rein) at (20.0,140.0)		
1100 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
1200 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 59.0 gallons of fuel		
1300 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 2930.0 gallons of water		
1400 292000ZAug99	resupply	292000ZAug99 300500ZAug99	Resupply A Company (Rein) 606.0 MREs		
1500 292200ZAug99	resupply	292200ZAug99 300500ZAug99	Resupply A Company (Rein) 3536.0 lbs of ammo		
N/A 300600ZAug99	Defend	N/A N/A	A Company (Rein)		

Figure 34: Event List Updated After Third Scheduler Output Displayed

Figure 35 shows the accumulated operating time and total sorties for each aircraft as displayed in the fourth scheduler output window. The aircraft that were changed from unavailable to available at the beginning of this last scheduler run were assigned a total of eleven sorties in this feasible schedule.

Schedule for time beginning 272111Z Aug99		
All missions were completed.		
Maximum Total Number of MV22 Sorties Required: 36		
OR		
Maximum Total Number of CH53E Sorties Required: 36		
Tail Number	Accumulated op time	Total sorties
MV22, 1	0	0
MV22, 2	7.867	4
MV22, 3	5.483	3
MV22, 4	1.983	1
MV22, 5	1.983	1
MV22, 6	5.717	3
MV22, 7	6.117	3
MV22, 8	1.983	1
MV22, 9	4.3	2
MV22, 10	4.3	2
MV22, 11	4.3	2
MV22, 12	4.3	2
CH53E, 21	7.6	3
CH53E, 22	7.95	3
CH53E, 23	7.767	3
CH53E, 24	5.7	2

Figure 35: Third Part of Third Scheduler Output

The planner found a feasible schedule for the second 24-hour transportation-planning horizon by making more aircraft available. This implies that several changes must be made to the aircraft maintenance and operations sections' current plans. The planner will first need to coordinate with the aircraft maintenance section to increase their efforts to ensure that the three aircraft in maintenance are ready after the first 24 hours of the operation. Next, the planner needs to coordinate with the aircraft operations section and recommend that the deception mission be canceled. If these changes are unacceptable, the planner will need to change the Resupply time windows. This may also change the Resupply policy by reducing the resupply trigger to a lower amount of each commodity on hand in each force. If none of these changes are acceptable, the planner should not recommend this Course of Action to accomplish the commander's mission requirement. However, if the maintenance and operations sections agree with these

changes or a modified resupply plan is feasible, the planner can continue examining this Course of Action by checking the third 24-hour transportation-planning horizon using the same technique outlined in the last three scheduler runs.

If the planner obtains a feasible distribution plan for the third 24-hour transportation-planning horizon, this Course of Action is a possible option to support the commander's mission requirement. The planner is now able to either recommend this Course of Action to the commander, or evaluate the feasibility of another Course of Action for comparison.

VI. CONCLUSIONS

Every unit that is not supported is a defeated unit.

Maurice de Saxe, Mes Reveries, XIII, 1732

Strategy and tactics provide the scheme for the conduct of military operations, logistics the means therefor.

Lieutenant Colonel George C. Thorpe, USMC

Forget logistics, you lose!

Lieutenant General Franks, USA, 7th Corps Commander, Operation Desert Storm

A. OBSERVATIONS

Sea-based sustainment of combat forces operating in a STOM environment requires a planning tool for managing the limited transportation assets at the sea-base. The sea-base of the 21st century will be similar to today's Amphibious Ready Group, with similar types of ship-to-shore transportation capabilities. While the operating environment may not change, the way we conduct operations will change drastically. Competition between operational and logistics aircraft missions place greater demand on these aircraft, further restricting the feasibility of sea-based operations. The exclusive use of aircraft to support the STOD network will limit the size and types of forces able to operate ashore. This may also limit the number and types of tasks that forces, operating at large distances, can accomplish. Traditionally, a logistics operation is only successful if the supported forces are not impacted by the logistics distribution system. However, in a STOM environment, SBL is the constraint that binds the size and type of the supported

forces and the distances at which they will operate. The SBLDSS provides a planning tool to help sea-based planners manage limited sea-based logistics resources, particularly the aviation assets, necessary to sustain the forces ashore.

B. RECOMMENDATIONS FOR FURTHER STUDIES

The SBLDSS developed in this thesis provides a planning tool for sea-based operational and logistics planners to determine feasible sustainment plans for a variety of courses of action. This is a prototype-planning tool that demonstrates how a decision support system might be developed by the Marine Corps and used to plan operational and logistics sustainment operations from a sea-base. While the focus of the thesis has been operational planning, the SBLDSS could also be used for wargaming and to analyze the following issues directly related to the STOM environment:

- Feasible force sizes and compositions facing a variety of mission requirements;
- The effect of distances from the sea-base to the objective and dispersion of forces operating ashore;
- New delivery containers, such as the Tactical Bulk Fuel Distribution System, and new liquid delivery techniques; and
- The impact of sending caches of supplies in the form of self-sufficient MCSSDs, Helicopter Support Teams, or Landing Force Support Parties;

C. RECOMMENDATIONS FOR FUTURE DEVELOPMENT

The Java program that defines the SBLDSS has been developed to allow additional features to be added to enhance the decision support system as an effective planning tool. Some of these features are listed below:

- A map display feature could be added to the program that shows force locations and the location of the sea-base. The map should be displayed on a contour map so terrain features are easily identifiable. The planner should be able to view force logistics status by clicking on the force icon with a mouse.
- A geographically referenced coordinate system should be added instead of the generic coordinate system currently used in the program.
- A save feature that allows the planner to save the force, event, and transporter lists is necessary to allow multiple course of action development and review.
- The SBLDSS should be tied to a data base containing logistics planning factors to allow the LPFs associated with the different Force Modules to change as the planner updates the T/O and T/E of the force. The planner would then be able to see the number of weapons and the number of rounds of ammunition the force has instead of the generic pounds of ammunition currently provided in this program. This feature should allow the planner to dynamically update data received from logistics data collection devices uploaded from the forces ashore.
- An improved scheduling algorithm could be developed to improve on the heuristic developed for the SBLDSS. The improvement algorithm might

iterate through a variety of rewards and penalties for aircraft accomplishing mission nodes and choose the best mix from these iterations.

- Surface transportation assets could be added to the program to allow multiple delivery modes. If this is done, either a new heuristic to determine STOD feasibility should be developed for both air and surface transportation assets, or a heuristic specifically focused on the surface lift assets should be developed.
- SBLDSS only allows single commodity resupply missions. Transporters and the scheduling algorithm could be modeled to allow for multi-commodity delivery.
- If developed as an operational planning tool, the SBLDSS must be rigorously tested. It should also be modified to comply with the Defense Information System Agency's Common Operating Environment for use with the Global Command and Control System and the Global Combat Support System.

The Marine Corps should continue to develop improved consumption models for a variety of forces to help predict sustainability of forces operating ashore in a STOM environment. This will help identify resupply requirements, and ultimately the number and/or capabilities required of the transportation assets at the sea-base. The 21st century warfighting environment reiterates the validity of the phrase "forget logistics, you lose" uttered by Lieutenant General Franks, USA, the 7th Corps Commander during Operation Desert Storm. The Marine Corps must keep this in mind as we continue to develop how we will fight in the 21st century.

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Code OR/So
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Naval Postgraduate School
Monterey, CA 93943-5000

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Code OR/BZ
Naval Postgraduate School
Monterey, CA 93955-5000

14. Associate Professor Kevin Gue 1
Code SM/BR
Naval Postgraduate School
Monterey, CA 93943-5000

15. Ms. Amy Jo Naylor 1
1917 Lake Road
Ontario, NY 14519

16. Norman L. Reitter 1
367 Ellisburg Road
Genesee, PA 16923